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REPORT OF THE COMMITTEE ON MARINE ECOLOGY AS RELATED TO PALEONTOLOGY

1944 - 1945

HARRY S. LADD, Chairman

Division of Geology and Geography
National Research Council
Washington, D. C.

NATIONAL RESEARCH COUNCIL
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NATIONAL RESEARCH COUNCIL

DIVISION OF GEOLOGY AND GEOGRAPHY

WASHINGTON, D. C.

* REPORT OF THE COMMITTEE ON MARINE ECOLOGY AS RELATED TO PALEONTOLOGY

1944-1945

Appendix H of Annual Report
of the Division for 1944-45

* (No. 5 in this Series)

COMMITTEE MEMBERS

Harry S. Ladd, Chairman
C. H. Edmondson — Earl H. Myers
Gordon Gunter — Roger Revelle
Remington Kellogg — F. W. Rolshausen
Kenneth E. Lohman — H. C. Stetson
T. Wayland Vaughan

(First edition, December 1945)
(Reissued without change, November 1950)

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REPORT OF THE COMMITTEE ON

MARINE ECOLOGY AS RELATED TO PALEONTOLOGY

INTRODUCTION

No meetings of the Committee were held during the year ending May 1, 1945 but, following the return of the Chairman to Washington, a meeting attended by a majority of the Committee was held at the National Museum on June 6, 1945. Committee members Gunter, Kellogg, Ladd, Lohman, Revelle and Vaughan were present, all, with the exception of Mr. Gunter, being at least temporarily resident in Washington. Also present at the meeting were: W. W. Rubey, Chairman of the Division of Geology and Geography, National Research Council, G. A. Cooper and Waldo L. Schmitt of the National Museum, Julia Gardner, John B. Reeside, Jr. and H. E. Vokes of the U. S. Geological Survey. A rough draft of the Committee's plan to prepare a treatise on marine ecology for the use of paleontologists was freely discussed. Gordon Gunter told of plans by the University of Texas for biological and ecological research in the Gulf of Mexico. Dr. Vaughan discussed certain aspects of the ecology of corals, Kenneth Lohman spoke on the ecology of diatoms and G. A. Cooper exhibited some remarkable groups of silicified brachiopods recovered from the Permian limestones of Texas.

As in former years, the Committee members have carried on a considerable correspondence with biologists and geologists in attempting to obtain information on current activities in marine ecology. The sharp decline in such activities caused by the war is strikingly reflected in the brevity of the section of "Current Activities" in this year's report.

No changes in the personnel of the Committee were made during the year but at the end of the war when the Committee begins actively to prepare the proposed treatise on ecology it is anticipated that a number of changes will be recommended.

TREATISE ON MARINE ECOLOGY

As noted in earlier reports, the Committee's plan to prepare a treatise on marine ecology for the use of paleontologists calls for the preparation of two annotated bibliographies:

(1) A Bibliography of Paleoecology prepared by geologists.

(2) A Bibliography of Marine Ecology. This will deal with those aspects of the ecology of living organisms that are of interest to paleontologists. It will be prepared by biologists who are aware of the needs of paleontologists and can review the voluminous biological literature with such needs in mind.

The Committee plans to use the material in the two bibliographies to prepare an integrated treatise on ecology that would be designed primarily for paleontologists. Prior to the meeting on June 6th, 1945 no definite

plans for starting work on the treatise had been made. At the meeting it was recognized that the completion of the bibliographies would require several years and that little progress could be expected until after the war. It was decided, however, that it would be wise to start work on the treatise without delay so that its completion would not lag too far behind the completion of the bibliographies. Accordingly, the Committee will prepare an outline of the treatise for next year's report. This will, admittedly be a tentative outline published in advance so as to be improved by criticism. Individual chapters will be assigned to geologists and biologists, the job of the Committee being to weld these into an integrated whole comparable in scope and treatment to the "Treatise of Sedimentation". Geography and chronology will be subordinated to types of environment.

BIBLIOGRAPHY OF PALEOECOLOGY

Only one additional assignment has been made in connection with the Committee's plan for the preparation of an annotated bibliography of paleoecology. M. K. Elias of the Nebraska Geological Survey will prepare material on the bryozoans. Earlier assignments on this subject have resulted in two papers that are included in the present report: "Possible Shallow-water Origin of Radiolarian Shale of the Mount Diablo Area, Middle California" by Bruce L. Clark and Arthur S. Campbell and "Paleoecological Conditions in the Ozark Region in Lower Ordovician (Canadian) Time" by James S. Cullison.

BIBLIOGRAPHY OF MARINE ECOLOGY

One additional assignment has been made: Louis W. Hutchins of Woods Hole Oceanographic Institution will cover the literature of living marine and brackish water Bryozoa.

CURRENT ACTIVITIES

MIDDLE UNITED STATES

Dr. Kenneth E. Caster of the University of Cincinnati has prepared a paper on Cretaceous "jellyfish" from Texas (abstract, Bull. Geol. Soc. Amer., vol. 55, p. 1465, 1944) and has studied the curious merostome and phyllocarid fauna of the lower Ordovician "sinkhole" deposit recently described by R. A. Laurence from Douglas Dam in east Tennessee (abstract, Bull. Geol. Soc. Amer., vol. 55, pp. 1465-66, 1944). At the present time Dr. Caster is on leave-of-absence as visiting professor to the University of São Paulo, Brazil.

Dr. M. K. Elias of the Geological Survey of Nebraska is continuing work on life relationships between algae and bryozoa; he is also studying associations of various adnate to penetrating organisms, comparing their fossil remains with similar structures produced by living marine organisms.

Plans for the establishment of a major marine station on the Texas Coast by the Institute of Marine Science of the University of Texas received a setback when a bill for appropriations was defeated by one vote at a recent session of the Texas legislature. The Institution is going ahead nevertheless, though the scope of its plan has been somewhat reduced. A small laboratory will be constructed at Port Aransas with funds donated by the General Education Board. A modest amount for running expenses and equipment was allocated to this project by the Board of Regents of the University and facilities for a small number of visiting investigators will be available. The Institution has recently established a new journal, known as Publications of the Institute of Marine Science. It will contain articles on all phases of the science of the sea, with particular reference to the problems of the Gulf of Mexico and the Caribbean region.

Dr. L. W. Stephenson of the United States Geological Survey is actively continuing his study of the Lewisville member of the Upper Cretaceous Woodbine formation of Texas. The Lewisville is a shallow-water facies and its large fauna contains many species of ecologic interest.

WESTERN UNITED STATES

Dr. R. W. Brown of the U. S. Geological Survey has finished a manuscript describing 5 fossil egg capsules of chimaeroid fishes, thus more than doubling the number of such specimens previously reported. The egg cases are found with fossil plants in brackish water or marine beds. Three of the specimens described by Brown are from the Upper Cretaceous of New Mexico, one from the Upper Cretaceous of Montana and one from the Oligocene of Alaska. Living chimaeroids are restricted to marine waters.

Drs. R. C. Moore of the University of Kansas and H. E. Vokes of the U. S. Geological Survey are studying a remarkably preserved mold of a fossil stalked crinoid from the lower Tertiary of Oregon. They report:

"The fossil includes the proximal part of the stem and the crown with outspread arms and pinnules. It is comparable to the splendid crowns of pentacrinids from the Jurassic of Europe, is unique among known Tertiary stalked crinoids, which are represented mostly only by very fragmentary remains.

"It is tentatively being referred to Isocrinus, although it is not, in all characters, strictly comparable with the modern representatives of that genus. The cup consists of radials and basals, infrabasals have not been observed; the rays have a three-fold isotomous branching, so that there are eight outer branches to the ray. At least thirty arms can be differentiated with certainty, and it seems probable that the actual complete number of arms was forty. Pinnules are well developed, and are mostly long and moderately slender; many reveal the presence of covering plates that stand in erect position along the sides of the ambulacral

grooves. The stem is stellate in section with nodal segments to which cirri were attached, and internodal segments. Typically there are seven internodals between each pair of nodals.

"The locality from which this fossil was collected represents strata from just above the middle of the Keasey formation. This formation is variously considered as being of uppermost Eocene or of lower Oligocene age; study of the molluscan fauna present in the formation seems to suggest that the latter assignment is to be preferred. The associated fauna at the locality from which the crinoid was obtained includes:

Solemya (Acharax) willapaensis Weaver
Nuculana washingtonensis (Weaver) new subspecies
Acila (Truncacila)nehalemensis G. D. Hanna
Yoldia (Portlandella) chehalisensis (Arnold)
Delectopecten new species
Tellina new species
Polinices new species
Fulgurofusus new species
Cancellaria new species
Exilia lincolnensis Weaver
Scaphander stewarti Durham

"The presence of Solemya and Delectopecten at this and other localities together with such forms as Lima (Acesta) oregonensis (Clark), a giant Lima similar to the modern L. (Acesta) agassizii Dall, two new species of Minormalletia, (otherwise known only from two Recent species dredged from 493 fathoms off the coast of Mexico) of large, thin-shelled gastropods, such as Turcicula columbiana Dall and Olequahia schencki Durham, and a dominance of Turridae, if not strictly in number of individuals, certainly in number and diversity of genera and species, suggest that the formation may have been deposited, and that the crinoid may have lived in relatively deep waters.

"Characteristic dissociated stem fragments of this species of "Isocrinus" are relatively common at some other localities; in addition, one locality has yielded stem segments which indicate the probable presence in the fauna of a second species of pentacrinid of unknown generic identity."

OUTSIDE THE UNITED STATES

Dr. H. E. Vokes, now with the U. S. Geological Survey, has completed Part III of his study of the Paleontology of the Lebanon Mountains, Republic of Lebanon. This section deals with the pelecypod fauna of the "Olive Locality" (Aptian) at Abeih. The report includes ecological data which suggest that the environment was that of relatively shallow waters possibly not deeper than 50 fathoms, of normal salinity over a sandy bottom. The report will be published by the American Museum of Natural History.

RECENTLY PUBLISHED PAPERS

Most of the papers listed below appeared during the year ending May 1, 1945.

GENERAL

Allan, R. S., The origin of the lower Devonian fauna of Reefton, New Zealand; with notes on Devonian brachiopods, Trans. & Proc. Royal Soc. New Zealand, vol. 72, pp. 144-147, 1943.

Andrews, Harry L., The kelp beds of the Monterey region, Ecology 26(1); 24-37, 1945.

Three faciations occur in the Monterey region. One is seasonal and two are permanent. The major number of animals are immature forms of species of the adjacent sea floor. The kelp protects during development. Animals, except for those imprisoned, leave the holdfasts at size of about 14 to 17 mm. The kelp beds check currents and wave action, hold bottom materials and reduce light.

Clark, Bruce L., Problems of speciation and correlation as applied to mollusks of the marine Cenozoic, Jour. Paleontology, vol. 19, pp. 158-172, 1945.

Clifton, R. L., Paleoecology and environments inferred for some marginal middle Permian marine strata, Bull. Amer. Assoc. Petrol. Geol., vol. 28, pp. 1012-1031, 1944.

Cooper, Byron N., Facies variations in the middle Ordovician of the Appalachian Valley in Virginia, (abst.), Bull. Geol. Soc. Amer., vol. 55, p. 1464, 1944.

Cullison, James., The stratigraphy of some lower Ordovician formations of the Ozark Uplift, Univ. of Mo., School of Mines & Metallurgy, Bull. Tech. Ser., vol. 15, no. 2, pp. 1-112, 1944.

Dendy, Jack S., The fate of animals when carried into lakes, Ecological Monographs, vol. 14, (3) pp. 333-357, 1944.

This paper concerns fresh water, but the conclusions may be of interest to marine ecologists and paleontologists. Most of drift animals entering lakes, settled to bottom immediately lakeward from margin of delta, where a zone of concentration was established. Wave action buried most creek animals or washed them ashore.

Dexter, Ralph W., The bottom community of Ipswich Bay, Massachusetts, Ecology 25(3); 252-259, 1944.

The bottom community is designated a Strongylocentrotus-

Buccinum biome contrasted to Strongylocentrotus-Agbuccinum biome of Shelford in a similar Pacific environment. The bottom is characterized and controlled by echinoderms, large gastropods, skates, sculpins, flounders and decapod crustaceans over sandy sediments. Islets of algae form a focus of attachment for small invertebrates. On solids a crust of algae and other organisms collect.

Edmondson, C. H., Incidence of fouling in Pearl Harbor, Occasional Papers, Bishop Museum, Honolulu, vol. 18, no. 1, pp. 1-34, 1944.

Elias, M. K., Auloporidae and Hederelloidea (and a system to avoid ambiguous use of generic names), Jour. Paleontology, vol. 18, pp. 529-534, 1944.

Ellisor, Alva C., Anahuac formation, Bull. Amer. Assoc. Petrol. Geol., vol. 28, pp. 1355-1375, 1944.

Emery, K. O. and Shepard, F. P., Lithology of the sea floor off Southern California, Bull. Geol. Soc. Amer., vol. 56, pp. 431-478, 1945.

Fox, Denis L., Biochemical fossils, Science, vol. 100, pp. 111-113, 1944.

Graham, Herbert W. and others, Biological results of the last cruise of the Carnegie, Biology - IV, The Phytoplankton, etc., Carnegie Inst. Wash., Pub. 555, pp. 1-92, 1943.

Graham, Herbert W. and Bronikovsky, Natalia, The genus Ceratium in the Pacific and North Atlantic Oceans, Biology - V, Carnegie Inst. Wash. Pub. 565, pp. 1-209, 1944.

Hoffmeister, J. E. and Ladd, H. S., The Antecedent Platform Theory. Jour. Geol., vol. 52, pp. 388-402, 1944.

Imlay, Ralph W., Cretaceous formations of Central America and Mexico, Bull. Amer. Assoc. Petrol. Geol., vol. 28, pp. 1077-1195, 1944.

Kay, G. Marshall, Mohawkian series of West Canada Creek, New York, Amer. Jour. Sci., vol. 241, pp. 597-606, 1943.

Kay, G. Marshall, Middle Ordovician of Central Pennsylvania, Jour. Geol., vol. 52, pp. 1-23; 97-116, 1944.

Ladd, H. S., Hoffmeister, J. E., and others, Geology of Lau, Fiji, Bishop Museum, Honolulu, Bull. 181, 1945.

Laurence, Robert A., An early Ordovician sinkhole deposit of volcanic ash and fossiliferous sediments in east Tenn., Jour Geol., vol. 52, pp. 235-249, 1944.

Lee, Richard E., A quantitative survey of the invertebrate bottom fauna in Menemsha Bight. Biol. Bull., vol. 86, pp. 83-97, 1944.

The area can be divided into 5 zones on a basis of bottom material. Life was richest on fine, mixed sand. The fauna of adjacent stations sometimes differed in quantitative and qualitative ways not associated with observed environmental differences.

Lee, Wallace and Payne, Thomas G., McLouth Gas and Oil Field, Jefferson and Leavenworth Counties, Kansas, Bull. 53, State Geol. Surv. Kansas, pp. 1-193, 1944.

MacNeil, J. Stearns, Oligocene stratigraphy of southeastern United States, Bull. Amer. Assoc. Petrol. Geol., vol. 28, pp. 1313-1354, 1944.

Murray, Grover E., Jr. and Thomas, E. Paul, Midway-Wilcox surface stratigraphy of Sabine Uplift, Louisiana and Texas, Bull. Amer. Assoc. Petrol. Geol., vol. 23, pp. 45-70, 1945.

Nicol, David, Paleoecology of three faunules in the Permian Kaibab formation at Flagstaff, Arizona, Jour. Paleontology, vol. 18, pp. 553-557, 1944.

Parkinson, Donald, The age of the reef-limestones in the lower Carboniferous of North Derbyshire, Geol. Mag., vol. 84, pp. 121-131, 1943.

Pyefinch, K. A., The intertidal ecology of Bardsey Island, North Wales, with special reference to the recolonization of rock surfaces, and the rockpool environment. Jour. Animal Ecology, vol. 12, pp. 82-108, 1943.

The stages in the recolonization of rock surfaces are described.

Revelle, Roger, Marine bottom samples collected in the Pacific Ocean by the Carnegie on its seventh cruise, Carnegie Inst. Wash. pub. 556, pp. 1-180, 1944.

Scrivenor, J. B., A further examination of organic remains in rhyolite-ash in Malaya, Geol. Mag., vol. 80, pp. 1-14, 1943.

Stearns, Harold T., Geology of the Samoan Islands, Bull. Geol. Soc. Amer., vol. 55, pp. 1279-1332, 1944.

Stenzel, H. B. and Turner, F. E., A miocene invertebrate fauna from Burkeville, Newton County, Texas, Amer. Jour. Sci., vol. 242, pp. 289-308, 1944.

Stenzel, H. B., Turner, F. E. and Hesse, C. J., Brackish and non-marine Miocene in Southeastern Texas, Bull. Amer. Assoc. Petrol. Geol., vol. 28, pp. 977-1011, 1944.

Stephenson, T. A., The constitution of the intertidal fauna and flora of South Africa, Pt. 2, Annals Natal Mus., vol. 10, pt. 3, pp. 261-358, 1944.

The paper is the second in a projected series of three. The first paper (Jour. Linnean Soc., (Zool.), vol. 40, pp. 487-536, 1939) gave an account of zonation in the intertidal belt and a detailed account of the distribution of the Patellidae. This second paper describes the distribution of the more important intertidal species and defines the geographical components of the fauna and flora. A third paper to be published later will include among other things a comparison of the results of Stephenson's group with those of other workers.

In this second paper it is concluded from a study of 318 species that the South African intertidal biota comprises four principal components: (1) a very large warm-water component supreme in the east but dying out to westward, (2) a smaller but important cold-water component paramount to westward but diminishing to eastward, (3) a component centered about the south coast and disappearing both eastward and westward, and (4) a component consisting of species which occur round the entire coast. Viewed in relation to the rest of the world the biota includes a large endemic element and a large East African, Indic or Indo-Pacific element. Other elements (Atlantic, sub-Antarctic, cosmopolitan, etc.) are present but apparently small.

Wimpenny, R. S., Plankton production between the Yorkshire coast and the Dogger Bank, 1933-1939. Jour. Marine Biol. Assoc., United Kingdom, vol. 26, pp. 1-5, 1944.

Zooplankton in net samples decreased from 1933-34 to a minimum in 1937-38 and increased again in 1939. The trend correspond to changes in mean surface salinity over the period, but not to the standing crop of phytoplankton.

Zimmerman, John, Jr., Tumey sandstone (Tertiary), Fresno County, California, Bull. Amer. Assoc. Petrol. Geol., vol. 28, pp. 953-976, 1944.

PLANTS

Andrews, Harry L., The kelp beds of the Monterey region, Ecology, vol. 26, pp. 24-37, 1945.

Brown, Roland W., Some prehistoric trees of the United States, Jour. Forestry, vol. 41, pp. 861-868, 1943.

Dexter, Ralph W., Ecological significance of the disappearance of eelgrass at Cape Ann, Mass., Jour. Wildlife Management, vol. 8, pp. 173-176, 1944.

Smith, Gilbert M., Marine algae of the Monterey Peninsula, Calif., Stanford University Press, pp. 1-622, 1944.

PROTOZOANS

Campbell, Arthur S. and Clark, Bruce L., Radiolaria from upper Cretaceous of Middle Calif., Spl. paper 57, Geol. Soc. Amer., 1944.

LeRoy, L. W., Miocene Foraminifera from Sumatra and Java, N.E.I., Colorado Sch. Mines, vol. 39, no. 3, 1944.

Lozo, Frank E., Jr., Biostratigraphic relations of some north Texas Trinity and Fredericksburg (Comanchean) Foraminifera, Amer. Midland Naturalist, vol. 31, pp. 513-582, 1944.

Palmer, Dorothy K., Notes on the Foraminifera from Bowden, Jamaica, Bull. Amer. Paleontology, vol. 29, no. 115, pp. 1-78, 1945.

SPONGES

Reimann, Irving G., New Hamilton Hexactinellida, (abst.), Bull. Geol. Soc. Amer., vol. 55, p. 1470, 1944.

COELENTERATES

Caster, Kenneth E., Hydrozoan Jellyfish from the lower Cretaceous of Texas, (abst.) Bull. Geol. Soc. Amer., vol. 55, p. 1465, 1944.

Ma, Ting Ying H., The climate and relative position of continents as determined by the growth rate of corals, pub. by author, Press of Fukien Provincial Bank, Yungan, Fukien, China, vol. 1 (Ordovician), vol. 2 (Silurian), vol. 3 (Devonian), 1943.

VERMES

Eller, E. R., Scolecodonts of the Silurian Manitoulin dolomite of New York and Ontario, Amer. Midland Nat., vol. 32, pp. 732-755, 1944.

Howell, B. F., Hamulus, "Falcula", and other Cretaceous Tubicola of New Jersey, Proc. Acad. Nat. Sci. Philadelphia, vol. 95, pp. 139-166, 1943.

Howell, B. F., New genus of Terebellid worm from the Pennsylvanian of Texas, (abst.), Bull. Geol. Soc. Amer., vol. 55, p. 1469, 1944.

Teichert, Curt, Parasitic worm in Permian brachiopod and pelecypod shells in Western Australia, Amer. Jour. Sci., vol. 243, pp. 197-209, 1945

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Condra, G. E. and Elias, M. K., Carboniferous and Permian Ctenostomatous Bryozoa, Bull. Geol. Soc. Amer., vol. 55, pp. 517-568, 1944.

Condra, G. E. and Elias, M. K., Hederella and Corynotrypa from the Pennsylvanian, Jour. Paleontology, vol. 18, pp. 535-539, 1944.

Condra, G. E. and Elias, M. K., Bicorbula, a new Permian bryozoan, probably a bryozoan-algae consortium, Jour. Paleontology, vol. 19, pp. 116-125, 1945.

Hertlein, Leo and Grant, U. S., IV, The Cenozoic Brachiopoda of western North America, Pub. Univ. of Calif. at Los Angeles, Math. and Phy. Sci., vol. 3, 1944.

Moore, Raymond C. and Dudley, Ruth Mary, Cheilotrypid bryozoans from Pennsylvanian and Permian rocks of the midcontinent region, Bull. 52, State Geol. Surv. Kansas, 1944. Reports of Studies, pt. 6, pp. 229-408, 1944.

MOLLUSKS

Burch, John Q., Distributional list of the West American marine mollusks from San Diego, California to the Polar Sea, Proc. Conch. Club of Southern California, pt. 1, Pelecypoda, 1945.

Coe, Wesley R. and Fox, Denis L., Biology of the California sea-mussel (Mytilus californianus). III. Environmental conditions and rate of growth, Biol. Bull., vol. 87, pp. 59-72, 1944.

Dexter, Ralph W., Annual fluctuation of abundance of some marine mollusks, Nautilus, vol. 58, pp. 18-24, 1944.

Dexter, Ralph W., Zonation of the intertidal marine mollusks at Cape Ann, Mass., Nautilus, vol. 58, pp. 135-142, 1945.

Engle, James B. and Loosanoff, Victor L., On season of attachment of larvae of Mytilus edulis Linn., Ecology, vol. 25, pp. 433-440, 1944.

In Milford Harbor (Connecticut) setting extended from early June to the end of August. The period of greatest intensity was mid-June to mid-July. The upper limit of setting was 1 to 2 feet above the mean low water mark. Between that level and the bottom setting was heavy. Setting usually occurred when the water was at mean low tide level.

Etherington, T. J., Free oil in ammonites, Columbia, South America, Bull. Amer. Assoc. Petrol. Geol., vol. 28, pp. 875-876, 1944.

Fleming, C. A., Molluscan evidence of Pliocene climatic change in New Zealand, Royal Society of New Zealand Trans., vol. 74, pt. 3, pp. 207-220, Dec. 1944.

Mr. Fleming has marshalled the molluscan faunas to explain the discordance between the morphologic and palaeontologic implications in climatic trends during the late Tertiary and post Tertiary. The generally accepted field evidence clearly indicates that the glacial epoch in New Zealand was of Pleistocene age. The evidence of the Mollusca indicates that no important lowering of the temperature is recorded by the faunas since the lower Pliocene.

In the mid-Miocene, New Zealand lay wholly within the subtropical zone of surface waters. No latitudinal zoning has been detected and the upper temperature limits are circumscribed by the absence of reef building corals. A progressive extinction of warm water Miocene genera such as Cucullaea, Isognomon, Pteria, Spondylus, Morum, Galeodea and Olivella was initiated near the close of the mid-Miocene and culminated in the lower Pliocene. The cooler water fauna which displaced the subtropical assemblage had no roots in the Miocene but was apparently introduced by a sub-Antartic tongue or current extending northward to Southern Hawke's Bay, at approximately 40° S. latitude. An ancestral warm current such as the present Notonectian current has been postulated which may have intercepted the waters flowing north from the Antarctic, checked the progressive cooling and blanketed the New Zealand seas during the Glacial period. Such a blanketing of the water would not necessarily, according to the author, greatly affect the land temperatures, which reached their minimum during the Pleistocene. Some evidence for such a discrepancy between the temperatures of the land and water may be afforded by Anadara trapezia (Linnaeous) one of the few species which apparently became extinct because of the Pleistocene refrigeration. The Recent representatives of the species are intertidal and lie half buried in the tropical mudflats along the east coast Australia. Exposure to heavy frost when the tide was out and the shells unprotected by the warm water might readily wipe out almost the entire population of Anadara along the flat.

The faunal provinces recognized in the New Zealand region today developed probably during the Pliocene but so little have the seas altered since that time that they remain true for the Recent oceanographic conditions.

The paper concludes with an excellent list of references. (Julia Gardner).

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Hackney, Anne Gray, List of Mollusca from around Beaufort, N. Carolina, with notes on Tethys, Nautilus, vol. 58, pp. 56-64, 1944.

Haas, Otto, The Vernay collection of Cretaceous (Albian) ammonites from Angola, Bull. Amer. Mus. Nat. Hist., vol. 81, pp. 1-224, 1942.

Ingram, William Marcus, Cypraeidae from the Admiralty Islands with therapy notes on their uses, Nautilus, vol. 58, pp. 129-134, 1945.

Mackay, Donald C. G., Gastropod shells, inhabited by Hawaiian Hermit Crabs, Nautilus, vol. 58, pp. 120-124, 1945.

MacLennan, Rhona M., The Association of Naiadites and Carbonicola in a part of the central coalfield of Scotland, Geol. Mag., vol. 80, pp. 52-55, 1943.

Nicol, David, Authorship and genotype of Schizodus, a late Paleozoic pelecypod, Jour. Paleontology, vol. 18, pp. 558-559, 1944.

Smith, Clay T., The biostratigraphy of Glycymeris veatchii in California, Jour. Paleontology, vol. 19, no. 1, pp. 35-44, 1945.

ARTHROPODS

Rothwell, W. Thomas, Jr., Preliminary ecological study of some Recent Pacific Ostracoda, (abst.), Bull. Geol. Soc. Amer., vol. 55, pp. 1470-71, 1944.

VERTEBRATES

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David, Lore Rose, Reliability in determination of bathymetric conditions of deposition based on fossil fish remains, (abst.), Bull. Geol. Soc. Amer., vol. 55, pp. 1467-68, 1944.

Gunter, Gordon, Studies on marine fishes of Texas, Pub. Inst. Nat. Sci. Texas, Univ. of Texas, vol. 1, no. 1, pp. 1-190, 1945.

Westoll, T. Stanley, The Haplolepidae, a new family of late Carboniferous bony fishes, Bull. Amer. Mus. Nat. Hist., vol. 83, pp. 1-121, 1944.

PROBLEMATICAL FOSSILS

Brown, Barnum and Vokes, H. E., Fossil imprints of unknown origin: II. Further information and a possible explanation, Amer. Jour. Sci., vol. 242, pp. 656-672, 1944.

Cloud, Preston E., Jr., The stromatolite gymnosolen not a salinity index, Amer. Jour. Sci., vol. 243, p. 108, 1945.

JAPANESE REPORTS

by

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As the Japanese people live largely by their fisheries, any information upon the fishing waters is of vital interest to their national economy. For that reason marine ecology is very much in the Japanese tradition and a number of biological stations have been operating under their flag. The factors governing marine life in the waters surrounding an island chain extending from about the latitude of Portland, Oregon, to that south of the Mexican border are much more complex than those along a continental shore of similar extent. The Japan Sea is an inland sea in the sense that the waters are cooler and differ in other qualities from those of the open ocean. The broad picture of land and water distribution has not greatly changed since the early tertiary and Japanese paleontologists have appreciated the necessity of considering ecological as well as time factors in interpreting the stratigraphy. Most of their statements and results seem too generalized to be of major interest. However, much of their work, and possibly the best of it, is written in characters unintelligible to most of us. The following abstracts were made from articles appearing in the journals most widely distributed in English speaking countries.

Yokoyama, Matajiro. Fossil Shells from Sado. Faculty of Science, Imp. Univ. Tokyo, Jour., Sec. 2, vol. 1, pt. 8, pp. 249-312, pls. 32-37, Sept. 18, 1926.

Although the paper is primarily systematic, the evidence for the correlation of the beds is presented at some length, and the ecology of the faunas considered because of its bearing on the correlation. The Sado fauna may be synchronous with the upper Musashimo formation of uppermost Pliocene or lower Pleistocene age. The larger percentage of northern forms in the Sado fauna is explained by its geographical position. Sado Island, lying a little south of the 38th parallel, is in the Japan Sea which is cooler than the Pacific Ocean waters near Tokyo. An unexplained feature of the Sado fauna is the small size of the gastropods in contrast to the medium or large size of the pelecypods. Not only are there an unusual number of normally small species such as Rissoids and Pyrammadellids, but genera of medium size such as the Muricids are represented by relatively small forms.

Yokoyama, Matajiro. Tertiary Mollusca from Southern Totomi. Faculty of Science, Imp. Univ. Tokyo, Jour., Sec. 2, vol. 1, Pt. 9, pp. 313-390, pls. 38-45, Dec. 24, 1926.

The Tertiary formation in southern Totomi includes 5 fossiliferous horizons of Miocene and Pliocene age.

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Yokoyama, Matajiro. Mollusca from the Upper Musachino of Tokyo and its Surburbs. Faculty of Science, Imp. Univ. Tokyo, Jour., Sec. 2, vol. 1, pt. 10, pp. 391-438, pls. 46-50, Dec. 24, 1926.

The paper like the preceding is primarily systematic. The fauna includes 272 species of mollusks and 2 of brachiopods and seems to have a slightly more northern aspect than that of the Recent seas in a similar latitude. Yokoyama includes under Northern Japan, that part of the country lying north of the 38th parallel, north latitude; under Central Japan, the part lying south of the 38th parallel, north latitude and east of the 138th meridian, east longitude, a line passing through Lake Biwa; Western Japan lies west of that line, and includes the Kinki District, the greater part of the Kii Peninsula, Chugoku, Shikoku and Kyushu. Southern Japan embraces all the islands south of Kyushu, such as the Satsunan Islands, the Ryukus, Formosa and the Bonins.

Matsumato, Hikoshichiro. On the Third Phase of Holocene in Northeastern Japan, as Evidenced by the Molluscan Fauna of Several Sites in the Province of Kikuzen. Tohoku Imperial Univ., Sendai, Japan, Sci. Repts. 2nd ser. (Geology) vol. 13, no. 3, pp. 45 (1) - 48 (4), 1930.

The molluscan faunas from 7 localities are considered. The period in which Ostrea gigas flourished is marked by the establishment of modern climatic conditions. The period as a whole and the faunal subphases are correlated with the Culture Stages.

Makiyama, Jiro. Stratigraphy of the Kakegawa Pliocene in Totomi. College of Science, Kyoto Imp. Univ., Mem., Ser. B, vol. 7, no. 1, pp. 1-53, 4 text figs., pls. 1-3 (2 fossil plates and 1 geologic map), Oct. 1931.

The Totomi section includes the following units:

Ogasa conglomerate (lower Pleistocene)
erosion
Soga series (upper Pliocene)
Upper Soga beds
Middle Soga beds (pyroclastic)
Lower Soga beds
epeirogenic movement
Kakegawa series
Ketienzian stage (middle Pliocene)
Ketienzi beds
Nango beds
Hosoya beds
Dainitian stage (lower Pliocene)
Tenno sand
Dainiti sands
Infra-Dainitian stage (upper Miocene)

Together they represent a complete cycle of sedimentation beginning with the coarser sediments of the lower Pliocene, followed by relatively deep water deposits, and concluding with the shallow water sediments of the upper Pliocene Soga series. Two types of deposition are recognized laterally, the typical Kakegawa and the synchronous Horinouti group, probably laid down in a deep trough in front of a mountainous hinterland. The lower Horinouti grades to the southeast into alternating sand and mud, repeated to a possible thickness of 2112 meters.

The Kakegawa group represents the normal facies laid down under a shallow sea. The basal beds, the Dainiti sands, include a discontinuous basal conglomerate of variable thickness, overlain by massive sand and thinly bedded sand and clay. Locally the sand is highly fossiliferous, and the unsorted shells are heaped up in lenticular masses. The upper sands are in part laminated. All of the fossils seem to be of shallow water origin. The bluish gray Tenno sand overlies the Dainiti and thins out toward the west. It may be fine and massive, or laminated and micaceous. The included fossils are not piled up as in the Dainiti sands, but are scattered and probably buried close to the places and in attitudes similar to those in which they lived. The Tenno Sea was slightly deeper than the Dainti and the beds are transitional to the deeper water muds and silts of the Ketienzian stage. The deeper water sediments are only sparsely fossiliferous. In the synchronous Horinouti deposits to the southeast, terrigenous material was washed out in quantity across the narrow continental shelf and rapidly silted up the trough in front of the shelf. The rhythmic repetition of sand and clay may be due to a shift in direction or change in velocity of currents, or to a series of climatic changes comparable to those recorded in the varved clays. The sands and clays are for the most part barren, but shells and Foraminifera indicative of warm water are associated with the basal and peripheral conglomerates.

The temperature of the Kakegawa seas was probably about the same as that of the present water around Kii peninsula. The Recent fauna of that area is referred to the Japonic Province and is governed by the warm Kurosio current. The salinity fluctuated very little. Almost no brackish water forms are included, and the fresh water Thiara totomiensis was probably carried in. The volcanic activity of the early Ketienzian may have exterminated much of the Daintian fauna. Many surface species, especially pteropods, are preserved in the calcareous nodules of the upper Ketienzi.

The Soga fauna probably lived in sublittoral waters free from sediments. Echinoids are abundant, especially in the lower beds. Suchium, a subgenus of Umbonium, is, like the echinoids, a scavenger on the sandy bottoms, and has been abundant from the Pliocene to the Recent. It is an exceptionally good guide, for the species are numerous and their range short.

The primary interest of the author is in the stratigraphic relationship of the beds, and the ecology is considered only in so far as it contributed to the interpretation of the stratigraphy.

Kuroda, Tokubei and Kikuchi, Kanzaemon. Studies on the Molluscan Fauna of Toyama Bay (1). The Venus, vol. IV, no. 1, pp. 1-14, 1 pl., 1 map, 4 textfigs., June, 1933.

Toyama Bay, about 60 miles across at the upper end, is one of the largest indentations on the western coast of Honshu. The 37° paralell passes through it. The bay is open to the northeast and partially shut off from the Japan Sea on the northwest by the long arm of the Noto Peninsula. The 200 meter line follows close to the southeastern shore and the depth in the middle of the bay exceeds 1400 meters. The shallow littoral bottom is pebbly or sandy but below 400 meters the bottom is covered by a fine mud. A warm coastal current, the Kiro-Siwo, influences the fauna of the upper waters but is not effective below 300 meters. The variety in the character of the bottom and the depth and temperature of the water tend to diversify the fauna. The following zones have been discriminated: 1. The bivalves boring in the calcareous sandstones of the tidal zone of the western shore are tropical and subtropical. 2. The littoral species from low tide mark to several meters' depth are similar to those on the southern and western shores of Honshu, Shikoku and Kyushu. 3. Sublittoral species similar to those of a similar depth of the southern shore of Honshu, live in waters up to 100 meters deep. 4. Below 300 meters, the fauna is boreal and includes Buccinum, Neptunea, etc. The zonation is not confined to the Mollusca, but is equally evident in the distribution of the fishes and Crustacea. If an assemblage such as that living in Toyama Bay were fossilized it probably would be subject to a number of interpretations. Differences of age and climate might be postulated to account for the differences due only to bottom conditions and shore currents.

Nomura, Sitihei and Hatai, Kotora. Catalogue of the Shell-bearing Mollusca from the Kesen and Motoyosi Districts, Northeast Honsyu, Japan, immediately after the Sanriku Tunami, March 3, 1933, with the Description of Five New Species. Saito Ho-On Kai Museum Research Bulletin no. 5, pp. 1-47, 2 pls., 1 text map, March, 1935.

The investigation followed the striking of the Tsunami, a tidal wave of great magnitude and destructive power, on the northeast coast of Honshu, north of Sendai. Shell sand and sandy gravel were collected at 11 localities along the Pacific beaches north and south of the line between Iwate and Miyagi provinces. From them, 240 species of mollusks, 94 pelecypods, 3 scaphopods, 138 gastropods and 3 Amphineura, were recovered. Species such as Nassarius festivus and Batillaria closely related to Potamides, commonly found in abundance in enclosed bays, are absent, but a few land shells are intermingled. These were doubtless brought down by the tidal wave and later they were thrown back on shore together with sponges, corals, annelid and nemertine worms, echinoids, crustaceans, brachiopods, and fish, to a distance of 100 to 200 meters.

The content and distribution of the assemblage indicates that the digging and shearing of the tidal wave is restricted to the littoral zone

and probably does not extend much beyond 10 meters in depth. Many of the shells recovered still contained their soft parts and some of them, a week after the tidal wave, were still alive. Water worn shells were rare, but those crushed by force were rather common. Deep water and pelagic forms were entirely absent and except for the small intermingling of land gastropods, all of the shells probably lived within the littoral zone.

The force of the tidal wave has been many times evoked to explain unusual associations in the fossil faunas. A study such as this may serve as a valuable check in the interpretation of similar assemblages.

Nomura, Sitihei and Hatai, Kotora. Pliocene Mollusca from the Daisyaka Shell-Beds in the Vicinity of Daisyaka, Aomori-ken, Northeast Honsyu, Japan. Saito Ho-On Kai Museum Research Bulletin no. 6, pp. 83-142, pl. 9 (1) - 13 (5), Sept.1935.

The fossil bearing beds are composed of coarse sandstone in part conglomeratic, and more rarely of an impure limestone. The fauna is typically northern, even slightly cooler than the adjacent water.

Coarseness and fineness of texture is not always a true indication of depth of water. In Matuchima Bay, near Sendai, the depth is only about 10 fathoms but the bottom is a bluish or blackish mud most commonly associated with deep sea deposits. The sediments at the Pacific entrance to the bay are relatively coarse, although the water is deeper than that in the basin.

The following notes were made on molluscan habitats:

Batillaria is commonly found crawling over the rocks or in brackish water near land-derived drainage. Littorina occupies much the same habitat but frequents regions influenced by coastal waves. Natica is prone to bury itself in the sand, leaving a trace of its travel route in the slightly raised level: it is a very active and a carniverous animal. Buccinum and its allies, also carniverous, are deeper water forms and are rarely strewn along the beach. Murex and Tritonalia are common on hard and rocky bottom within the littoral zone. Tegula and Monodonta are littoral and common on rocks or in tide pools. Haliotis is also a rock dweller but may have a greater range in depth. Mytilus, Volsella and Septifer assemble in the crevices in the littoral zone, adhering to the rocks and to each other by their byssi. Solen is most commonly found on sandy bottoms in or very near the littoral zone. Paphia, Venus and Arca inhabit both the sandy and the muddy shores but prefer the sand. Lithophagus, Pholadidea and Petricola bore into the rock, coral or other shells.

The northern forms inhabit relatively deeper water than the southern. Deep water species are usually thin and dull; the shallow water forms are more commonly thick shelled and brilliant in coloring. An increase in salinity commonly produces a thin shell, but species living on shallow but muddy bottoms such as Clementia and Anodontia may also have thin shells.

Nomura, Sitihei. Miocene Mollusca from Siogama, Northeast Honsyu, Japan. Saito Ho-On Kai Museum Research Bulletin no. 6, pp. 194-234, pls. 16 (1) - 17 (2), Sept. 1935.

The fauna considered is in the upper part of the Siogama formation, probably of middle Miocene (Vindobonian) age. Two zones have been recognized, the lower characterized by Cardium ciliatum, the upper by Cultellus izumoensis. The two beds show very little relationship to each other in their essential faunal elements. This is explained in part by the inadequate collection from the lower horizon. Both faunas were apparently laid down in very shallow water in an enclosed bay similar to the recent Siogama Bay. The Moniwa shell beds developed in the western part of the city of Sendai may be a little older than the beds outcropping around Siogama Bay but the differences are probably due in large part to facies. The Moniwa shell beds were probably laid down under the agitated water of the open sea, while the Cardium and Cultellus faunas were deposited in an enclosed basin.

The greater part of the paper is concerned with the systematic treatment of the fauna.

Nomura, Sitihei and Hatai, Kotora. Fossils from the Tanagura Beds in the Vicinity of the Town Tanagura, Hikusima-ken, Northeast Honsyu, Japan. Saito Ho-On Kai Museum Research Bulletin no. 10, pp. 109-155, 5 pls., Aug. 1936.

The paper is primarily systematic, but observations have been made upon the probable ecological conditions. The sediments were presumably laid down along the margin of a northwest-southeast trending fault line during the lower part of the middle Miocene. At the margin of the basin, where the depth of water was probably about 5 to 10 meters, the sandstone is coarse grained and cross bedded. Balanus is a common form in the sparse fauna. All of the shells are fragmentary except for a single brachiopod, Magadina cumingi, remarkable for its heavy shell and strong hinge equipment. In the central part of the basin, where the depth of the water may have reached 20 to 30 meters, the assemblage is larger, more diversified, better preserved, and the sediments are finer and more clayey. Even in the coarser but evenly bedded sandstones, presumably out of the range of strong coastal waves, the shells are entire and well preserved. The most widely distributed and characteristic association of the deeper water includes zonal markers of Pecten, Cardium, Dosinia, Polinices and Nassarius. Both cool and warm water species are intermingled, indicating intermittent southern currents.

Nomura, Sitihei and Hatai, Kotora. Fossils from Yazawagi-mura, Ugo Province, Northeast Honsyu, Japan. Saito Ho-On Kai Museum Research Bulletin no. 10, pp. 157-181, 1 pl., Aug. 1936.

The work, primarily systematic, is concerned with a basal middle Miocene fauna included in a coarse grained sandy clay. Pecten and Terebratulina are abundant. The unusually small size of the Mollusca in

the lowest beds is interpreted as a primitive character, rather than one due to an unfavorable environment. The larger species in the higher beds are presumably their descendants. The sediments and fauna indicate deposition in an open embayment at a depth of 30 to 50 fathoms under temperature conditions not unlike those of the present day. Fairly rapid subsidence and a bottom cleared of land-derived material are inferred from the abundance of the brachiopods. Such conditions are most commonly met in a sinking fault graben.

Nomura, Sitihei and Hatai, Kotora; On the Geographical Distribution of Certain Marine Shell-Bearing Mollusca and their Geologic Significance, Saito Ho-On Kai Museum Research Bulletin no. 10, pp. 195-208, Aug. 1936.

The historical development of our information is considered at length and Chamberlain and Salisbury, Dall, Woodring, Grant and Gale, Yabe and Nomura and Yakiyama are quoted. An analysis of faunal records has been made; the following general conclusions are based upon the studies of 47 species of Mollusca and 3 species of Terebratulina.

Migrations during the upper Oligocene trended along the northern border of the Pacific from the Californian to the Japanese coast. According to deductions based on Thyasira bisecta as a temperature indicator, cold water currents were effective at least as far south as central Japan. During the Miocene, the warm water currents returned, carrying Vicarya far to the north and distributing Miogypsina and Lepidocyclina on both sides of the Pacific. Thyasira bisecta invaded southern waters a second time, either at the close of the Miocene or more probably at the beginning of the Pliocene. The maximum cooling of the Pliocene, marked by the introduction of Alaskan and Californian species into the western Pacific, was probably in part synchronous with that invasion. Scattered later evidences of short and local warm water invasions have been observed but the glacial and interglacial stages are not so well defined in Japan as they are in Europe and North America.

Nomura, Sitihei and Hatai, Kotora. A Note Concerning Data on the Bathymetric Range of Certain Marine Animals and Remarks on the Geology of the Neogene Formations in Northeast Honsyu, Japan and Their Depth of Sedimentation as Indicated by the Fossil Fauna. Saito Ho-On Kai Museum Research Bulletin no. 10, pp. 231-318, Aug. 1936.

The article is an extensive compilation of material which may have some bearing on the problem of the depth of the paleo-seas. A number of long recognized observations are made on the relation of the shell to its environment. A large number of dredging records of all classes of marine organisms are assembled. The views of Twenhofel, Ruedemann, Shepard and Thorp on the evidence afforded by the lithology of the sediments are considered at length. A number of Tertiary sections from northeast Honshu, together with faunal lists from the various beds, have been brought together.

The paper offers little that is new, either in facts or in interpretation but it doubtless forms an excellent background for future investigations.

A bibliography of 344 titles concludes the paper.

Nomura, Sitihei and Hatai, Kotora. A Note on the Zoological Provinces in the Japanese Seas. Biographical Soc. Japan, Bull. vol. 6, no. 21, pp. 207-214, pl. 13. September 1936.

M. Yokoyama, 1920, the first to delimit zoological provinces, was a paleontologist. He established his regions in order to consider more intelligently the natural assemblages of Mollusca and the climatic conditions under which they lived. Some later modifications have been made. The following, sketched on Plate 13, are those of Nomura and Hatai:

Pacific Ocean from the northern Kuriles to Taiwan.

1. Hokkaido-Kuriles Province from Tugaru Strait north to the Bering Sea.

2. Sanriku-Zyoban Province from Tugaru Strait south to Tyosi Peninsula.

   a. Myako subprovince from Tugaru Strait south to Kinkazan.
   b. Matusima subprovince from Kinkazan south to Onahama.
   c. Kasima subprovince from Onahama south to Tyosi Peninsula.

3. Kii-Kwanto Province from Tyosi Peninsula south to Kii Peninsula.

4. Kyusyu-Sikoku Province from Kii peninsula, south along the Pacific coast of Sikoku and Kyusyu to line drawn south of Tusima Island.

5. Taiwan-Ryukyu Province including Ryukyu, Amana-O-sima and Taiwan.

Japan Sea from the western coast of Hokkaido to northern Kyusyu.

6. Uetu Province from Tugaru Strait south to Noto Peninsula.

7. Noto-San-In Province from Noto peninsula south to northern Kyusyu.

The northern limit of distribution of certain species is the critical factor in placing the boundaries. The southern distributional limit, as a

rule, is less sharply defined. The line between Kii-Kwanto and Kyusyu Provinces is the northern limit of commercial corals, Corallium japonicum and C. junojoi.

Nomura, Sitihei. Molluscan Fossils from the Tatunokuti Shell Bed Exposed at Goroku Cliff in the Western Border of Sendai. Tohoku Imperial Univ., Sendai, Japan, 2nd. ser., vol. 19, pp. 235 (1) - 275 (41), 1 textfig., pls. 33 (1) - 36 (4), 1936.

The Tatunokuti bed of probable lower Pliocene age includes the fossiliferous tuffaceous shale and sandstone strata exposed on a deep gorge on the western border of Sendai. The fauna is large and well characterized. The species are few compared with the high number of individuals and in number of species, the pelecypods greatly exceed the gastropods. Many of the pelecypods are large and heavy shelled, but there are no large gastropods. Both single and double valves of pelecypods are common, and one shell layer is composed almost entirely of the upper valves of Anomia cytaeum. None of the shells are waterworn and there are few fragments. The irregular arrangement of the heaps of well preserved specimens indicates that the fauna may have been carried by tidal currents and for only a short distance. The majority of the species are sand or mud dwellers, but a few forms are restricted to rocky beaches. All of them are essentially shallow water or brackish. The fauna has a northerly aspect with no intermingling of southern species, and the waters must have been decidedly cooler than the present seas.

Nomura, Sitihei and Hatai, Kotora. On the Variation of Neptunea arthritica Bernardi from Northern and Central Honsyu, Japan. Saito Ho-On Kai Museum Research Bulletin no. 13, pp. 1-5, 2 pls., Aug. 1937.

Neptunea arthritica is a common whelk in the waters around northeast Honshu, Hokkaido, the Kuriles and along the northeastern coast of Asia. It is also recorded in the Pleistocene of east-central Japan, the southern limit of the species in the Recent seas. The southern shells are relatively small and smooth; the shoulders gently rounded and nearly devoid of tubercles; the aperture narrow. Toward the north the shells tend to increase in size, the spire becomes higher, more angular and more tuberculated, and the aperture more expanded. The lowered temperature of the sea water rather than difference in depth seems to be the controlling factor.

The two Pleistocene species most closely resemble Recent forms inhabiting a range a little to the north of Honshu-Kwanto, the area in which the fossils have been found.

Nomura, Sitihei and Hatai, Kotora. Preliminary Notes on Some Sand-pipes. Saito Ho-On Kai Museum Research Bulletin no. 13, pp. 147-153, 2 textfigs., Aug. 1937

Sand pipes are a common phenomenon both along the Recent shores and in various geological formations. Studies have been made on sand filled

crab burrows in the brackish zone along the Formosan shores; on the Lingula burrows in the hard muds not readily disturbed by the tide; on mud burrows made by mollusks such as Panope, Mya, Solen, Cultellus and Solecurtus; and on sea-cucumber and annelid burrows in the sand and sandy mud. However, except for genera such as Teredo and Lithodomus, exceedingly few of the burrows are associated with remains of the organism which produced them. On the contrary, in strata where abundant sand pipes are found, marine fossils are rare or absent and where marine fossils are abundant, sand pipes are absent. Probably some of the pipes may be due to the former roots of plants although the woody substance may be secondary or absent. The possibility of their association with marine algae is not considered. Many of the fossil sand pipes may be related to concretions and of chemical or physical rather than organic origin. The attitudes of the pipes within the beds are not constant. Some are vertical, others oblique but none are parallel. Sections of 3 different types of pipes and outlines of the terminal portion are given.

The problem of the pipes is stated and reviewed but not resolved.

Nomura, Sitihei and Zinbo, Noboru. On Some Neogene Mollusca from Yamagata Prefecture, Northeast Honsyu, Japan. Pt. I. List of the Miocene Fossils from the Vicinity of the Ginzan Hot Spring, Northeast Slope of the Hunagata Volcano. Saito Ho-On Kai Museum Research Bulletin no. 13, pp. 155-157, Aug. 1937.

The fossils were mostly taken from a rather compact, dark green to yellowish gray brecciated tuff, sandy and conglomeratic locally.

The primary interest in the fauna rests on the large number of Miocene species characteristic of the Pacific drainage. Their presence in the borderland of the Japan Sea implies a marine Miocene seaway between the Pacific Ocean and the Japan Sea. Fifty-five species are listed.

Hatai, Kotora. Classified List of Papers and Reports Bearing on Palaeontology Published in Japan During 1900-1936 (with several earlier works). Part I. Invertebrata, Mammalia and Stratigraphic Palaeontology. Saito Ho-On Kai Museum Research Bulletin no. 13, pp. 189-257, Aug. 1937.

The list is incomplete but it probably covers all of the articles appearing in the 42 listed Journals. The 1322 titles are assembled under the following headings:

Foraminfere	98
Spongiae	25
Anthozoa	71
Hydrozoa	20
Criniodea	6
Asteriodea	5
Ophiuroidea	6
Echinoidea	20
Bryozoa	16

Brachiopoda	61
Pelecypoda, Gastropoda, and Scaphopoda	372
Cephalopoda	56
Decapoda	40
Encrustacea	4
Cirripedia	19
Trilobita	9
Pisces	12
Reptillia	1
Miscellaneous Paleontology	61
Miscellaneous	11
Oceanographic	36
Distribution	10
Insecta	4
Mammalia	119
Stratigraphic Paleontology	240

Similar bibliographies covering single years appeared in later numbers of the same Journal.

Nomura, Sitihei. On the Molluscan Fauna Dredged from Matusima Bay during Feb. 10-13th, 1937 By Dr. S. Yoshimura. Saito Ho-On Kai Museum Research Bulletin no. 19, pp. 1-12, 6 textfigs., 1 table, 1 map, July 1940.

The molluscan fauna was dredged from 33 stations in Matusima Bay. The species have been identified and listed, the number of specimens given and a tabulation made of the depth, the bottom temperature and the character of the bottom.

COLLECTING RECENT FORAMINIFERA

by

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Many paleontologists and biologists now in the Armed forces are enjoying their first opportunity to collect and study marine organisms in relation to their natural environment, and from the numerous collections now being received by schools and museums it seems probable that other students have both the time and the interest to extend this work should instructions be made available.

Although the Foraminifera are the most numberous and widely distributed biotic constituent of marine sediments, first attempts to collect them in appreciable numbers within the intertidal zone usually end in disappointment. An occasional sample of beach sand will consist for the most part of partially eroded tests but the majority of samples will contain few if any. Seaweed and grass growing under certain conditions are heavily encrusted with Foraminifera and although the washings from seaweed are a dependable source, samples taken at random are seldom worth the effort. Mud from a hoisted anchor affords an opportunity that should not be neglected, but the putrid mud bottom and occasional periods of low salinity in many harbors are unfavorable to most species.

One of the main pleasures to be derived from field work is to learn where to look for a particular species and to distinguish the natural habitat from those areas in which the skeletal elements accumulate due to current action. Foraminifera cannot survive in the shifting sand of the beach, and on a rock bound coast those areas exposed to surf action are unsuited to these Protozoa, except for the small niches formed by the holdfasts of algae and mussel beds.

The equipment for collecting at the beach and dredging at moderate depths is readily available, as are the materials for concentrating and shipping samples. A suitable hand lens having a wide field and 10 diameters of magnification or its equivalent is carried by every biologist and paleontologist, and a vaseline or other wide mouthed bottle is convenient for observing washed samples. In tropical and subtropical regions the color varies with the species, and under direct illumination will range from white through shades of green, orange, red, brown, blue and lavender. Should a few living Foraminifera be placed in an observation bottle filled with sea water and the bottle allowed to remain motionless on its side for five minutes, many of the Foraminifera will become attached and one may then, with aid of a hand lens and by carefully shielding the light, observe the pseudopodia.

BEACH SAND

Quartz sand rarely contains appreciable numbers of Foraminifera. However, riffle marks on a firm gently sloping beach occasionally consist for the most part of well preserved tests. A piece of tin or stiff paper and a knife are useful in removing this material, and much of the heavier sand may be eliminated by placing the sample in a tin can or other wide-mouthed container filled with water and agitating until the lighter sediments including the Foraminifera work to the top. The sample is then recovered by washing or scraping the surface material into a second container. Occasionally coral sand contains many Foraminifera, the majority of which are badly eroded and are not easy to separate from the sand. Sea cucumbers on the coral sand bottom of lagoons ingest the surface sediments, including living Foraminifera, and many perfect specimens may be easily recovered by removing the gut and stripping out the contents.

SEA WEED AND GRASS

Washings from sea weed and grass taken in areas exposed to the surf usually contain few Foraminifera, but when growing in sheltered tide pools or on a submerged tidal flat protected by an outer reef, these washings often yield a nearly pure collection of both large and small species. Weeds having rigid stripes, the corallines, and those forming turf-like growth are favorable sources, but where there is an appreciable surf the holdfasts and the material that comes away with them usually prove superior. When the Foraminifera are abundant it is only necessary to shake the weed vigorously in a container filled with sea water to detach them, but attached species often require that the weed be washed vigorously between the hands. Coarse debris may be removed from the washings with the fingers, or better by passing them through a piece of netting that will not retain the larger tests. Silt and other debris can be removed from the sample by repeated washings, care being taken that sufficient time is allowed for the smaller Foraminifera to settle before the water is poured off. Excess sand may be removed by the method described above, but in many regions this is unnecessary. At times it is advisable to use the thin blade of a knife to lift large fragile disk-shaped or encrusting tests from the surface of the grass and weeds.

CORAL REEF AREAS

Few Foraminifera are to be found in the vicinity of living corals, and surf-washed dead corals are a poor source. Dead corals covered by a moss-like growth of algae within a lagoon or on the platform back of the living reef are the best places to look for those large sessile branching species that so closely resemble colonies of corals, and the larger encrusting species. Certain of these are bright red in color and are easily recognized. A vigorous washing of the dead coral will remove most of the Foraminifera and the washings should be handled in the manner described above. More perfect specimens may be obtained by retaining bits of coral, and removing the Foraminifera with the blade of a knife.

DREDGING

Various coring devices and snappers are convenient for taking subsurface samples. A suitable coring device can be constructed from pipe fittings in almost any shop. When these are not available a suitable dredge can be constructed, or a bucket at the end of a strong rope may be used to obtain adequate samples at moderate depths. To build a dredge one needs a short length of pipe, an old sock, a piece of canvas and some heavy cord. Remove the foot of the sock, and slip the cut end over one end of the pipe. Wrap a piece of canvas one and one-half times around the pipe and whip both the canvas and the sock firmly to the pipe. Where the bottom is rough the sock would not last a single towing if it were not for the canvas guard. Lash the pipe for the most of its length to the end of a line, tie off the end of the sock with a piece of strong twine, and the dredge is ready to use.

A dredge that I have found convenient was made as follows: The end of a piece of two-inch pipe six inches long was split with a hacksaw by two parallel cuts three-eights of an inch from either side of the midline, and one inch deep. A five-sixteenth inch hole was then drilled in the center of each of the two three-quarter inch sections to receive the bridle. The pipe was heated and the two wide sections pounded down to form broad flat blades that dip slightly below the wall of the pipe. The edge of each blade was sharpened from the outside on an emery wheel, and the ends of the two lugs rounded. The bridle or bail was made from a quarter-inch piece of round iron ten inches long by making an 80° bend one-half inch from each end and a sharp bend in the middle so that the two ends of the rod could be sprung into position from the inside of the pipe. This bridle should swing freely. The bag was made from a piece of number 25 bolting silk six inches wide and eight and one-half inches long, the silk being reinforced by sewing a two-inch strip of unbleached muslin to one of the eight and one-half inch sides to protect the silk from the iron pipe, and a three inch strip to the opposite side to form the bottom of the bag. From this a tube was formed by sewing the ends of the three strips together with a French seam. The tube was then whipped to the pipe and a stout cord sewed near the middle of the wide muslin band with which to tie off the end of the bag. Protection for the bag was obtained by whipping two over-lapping pieces of canvas six inches wide to the opposite sides of the pipe and trimming them so that they formed a tube that extended slightly beyond the end of the bag.

When used from the deck of a ship or in a strong current it is advisable to attach a suitable weight to the line about two feet above the dredge, so that the dredge may be used when the line forms only a small angle from the vertical. Mud samples should be repeatedly washed to remove the silt and clay, the same precautions being used as in washing samples from sea weed. Sandy samples may be concentrated as previously described unless the major portion of the sample is calcareous in nature.

PELAGIC FORAMINIFERA

While at sea a plankton net held under a fire hydrant situated near the intake for the ship's condenser system may yield pelagic Foraminifera. These are most interesting to observe in the living condition because of the color and the long spines when present, but the numbers taken usually do not warrant the effort, and it is often possible to take similar numbers from the shore where working conditions are usually more favorable. Deep hauls with a large net occasionally yield vast numbers of these foraminifera but this requires a winch and other special equipment.

OTHER SOURCES

Washings from algae, bryozoans and hydroids growing on the carapaces of certain arthropods and on the shells of large mollusks often provide interesting material. Empty shells, and other objects in shallow water should also be examined for attached species. Many marine organisms, including arthropods, echinoderms, and annelids ingest enormous numbers of Foraminifera and the content of the gut should be examined. The stomachs of certain astropectins often contain thousands of Foraminifera that still retain their natural color. Scrapings from the hulls of ships often yield Foraminifera other than those found locally, and it would be interesting to know if the scrapings from whales ever includes these Protozoa.

STORING AND SHIPPING

Dried samples are light and easily handled. A suitable paper container for small samples may be made from a 5x8 inch piece of stout paper as described below. (This description is based on a container sent me by Mrs. Helen Jeanne Plummer).

1. Fold the paper lengthwise through the middle.

2. Form a flattened tube by folding over one-fourth inch along the open edge.

3. Reinforce the seam by making a second quarter-inch fold.

4. Turn the paper over so that the closed seam is down, and away from the body -- now fold the upper corners down so that the open ends of the tube are parallel with the lower edge. The paper is now truncate in shape, the two ends forming an angle of 45° with the lower edge.

5. Fold the two lower corners up so that what was a portion of the lower edge is now parallel with the outer edge of the vertical portion of the seam. The two ends of the tube now terminate at an angle of 90°.

6. Lift the corners folded last and insert these under the edge of the closed seam. One should now have a container that is closed at both ends, and will retain the finest sediments without bursting open unless filled too full.

7. Label the tube and then open one end to receive the sample.

8. In shipping each container should be wrapped separately so that in case of breakage the samples will not become mixed.

When it is desirable to preserve the protoplasmic content of the tests the sample should be killed and stored in 10% formalin that has been saturated with baking soda. Better results will be obtained if the preservative is used at 65° C. These wet samples when stored in the dark will retain much of their color for several years and the most delicately ornamented test will not deteriorate.

CONCLUSION

In my collection I have four ounce samples from riffle marks, washings from weeds, beach sand, and hand made dredgings that for the most part consist of the tests of Foraminifera. These are exceptions, for the majority of samples contain much extraneous material.

Samples without adequate labels are worthless and it is wise to include a small label in the sample in addition to the one on the container. A card above my work table reads "Label it now or throw it out". This inscription was suggested by the numerous collections of minerals, shells, skins of birds and other material received by schools and museums that would have been of value to science had the collector made certain that suitable labels were attached in such a manner that they would not become lost.

It is inconvenient to take field notes, but one should not trust to memory. These notes should include the date, location, method used in taking the sample, local physical and chemical conditions as suggested by the depth, proximity to the shore, turbidity, the nature of the sediments and the occurrence of rivers that might have a seasonal influence upon the salinity. A single temperature reading may be of little value and again it might be of considerable interest. I once found enormous numbers of living Foraminifera in a lagoon where the water was painfully warm to the upper limbs. Unfortunately no thermometer was available, but it seemed certain that the temperature was in excess of 39° C. The value of field notes lies in the growing interest in marine ecology in relation to paleontology and stratigraphy.

DIATOMS AS PALEOECOLOGICAL INDICATORS

by

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Any assemblage of fossil diatoms contains a mixture of species and varieties that have a long geologic range and are still represented in living floras, together with a number of short-ranging forms that are diagnostic of stratigraphic zones. The short-ranging forms may have very short ranges indeed — many genera are confined to the Upper Cretaceous, several to the middle Miocene, and many extinct species are known from rocks or upper Pliocene and even Pleistocene age. On account of the phenomenal ease with which they are dispersed diatom species spread over great distances in a relatively short time, and this has been true in the past. For example, extinct genera and species found in the middle Miocene strata only in California are similarly found only in beds of the same age in such widely separated localities as Maryland, Virginia, and Italy. Associated with these short-ranging species are other species which are still represented in living floras. Thus the complete assemblage contains species which are useful for age determination and also species useful for paleoecological interpretation.

In making these paleoecological interpretations, care must be exercised to distinguish introduced or re-worked forms. With mollusks and the larger fossils generally, it is often possible to determine with reasonable certainty whether the organism died in its natural habitat or was transported to its final resting place after death. This is very much more difficult to determine for microfossils such as diatoms, and particularly so for the pelagic forms, which may reach their final resting place on the ocean floor many miles from the locality in which they lived. Many of the littoral forms, particularly those which grow attached to other organisms, rocks, etc., are probably finally incorporated into sediments at or near the site of their habitat. The littoral forms, therefore, are much more suitable for interpreting the ecological conditions that existed at the time the organisms were living. Re-worked diatoms, those which have been eroded from earlier sediments and re-deposited, are often difficult to detect. There are many areas today in which Pliocene, Miocene, and older diatomaceous sediments are being eroded and are contributing diatoms to recent sediments, and this same process has been going on in the past. Many of the re-worked forms are conspicuous by their broken or otherwise damaged condition, or show the effects of partial solution or leaching. Such re-worked forms are usually the least abundant in an

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assemblage, or they may represent a totally different ecological environment than the bulk of flora. For example, species characteristic of alpine lakes are obviously introduced or re-deposited when found in a marine diatomite.

One important assumption must be made in all paleoecological studies, namely that the environmental conditions under which the organism lived in the past were approximately identical with those in which it lives at the present time. The validity of this assumption is capable of only partial proof, and although it will never be proved or disproved with the elegance of a mathematical theorem, nevertheless a considerable body of evidence has been accumulated that indicates its usefulness as a working hypothesis.

Diatoms exist today under a great variety of habitats, such as fresh water, brackish water, saline lake water, and sea water, and at temperatures ranging from that of ice to that of hot springs. Very few species are tolerant of large changes in either temperature, pH, or salinity. Many genera and thousands of species, for example, live only under marine conditions, a slightly smaller group live only in fresh water, and a still smaller group inhabits only brackish water. Each of these habitats may be subdivided into others based on degree of salinity, temperature, pH, etc. Many of these species of restricted habitat, however, have long geologic ranges, and when found in a fossil deposit are useful in making paleoecological interpretations. Independent paleontological and stratigraphic information is available regarding many fossil diatom-bearing beds, and in every example of this kind known to me paleoecological interpretation made on the basis of diatoms agrees with similar interpretations made on the basis of larger fossils occurring with them. Thus some assurance is felt in making paleoecological interpretations on the basis of diatoms when they are the only fossils present.

The occurrence of a single species of diatom may yield some ecological information, indicating, for example, whether a deposit is marine or nonmarine, but an assemblage of many species provides a basis for much more precise determination of the environment under which the diatoms lived before deposition. The number of species in an assemblage may range from less than 25 to more than 300. A list of diatoms showing the relative frequency of each species in the assemblage, provides a basis for determining such ecological conditions during deposition as fresh water, lacustrine, saline lacustrine, fluviatile, peat bog, brackish estuary, tidal lagoon, shallow water marine, open sea, etc. The temperature of the water is indicated at least to a three-fold breakdown of cold, temperate, and warm, and often more closely.

All paleoecological interpretations based on fossil diatoms depend upon an accurate and complete knowledge of the environmental conditions under which present day floras live. The degree of completeness of this fundamental information becomes a measure of the degree of accuracy of the final interpretation. I urge and plead, therefore, that all students of living diatoms publish, in addition to the accurate identifications and

relative frequencies of species, as much ecological data as possible, particularly such factors as temperature, type of habitat, salinity, and pH. These are the tools of the paleoecologist, and without them he is powerless to do more than speculate, with the maddening conviction that the truth lies just beyond his grasp.

POSSIBLE SHALLOW-WATER ORIGIN OF RADIOLARIAN SHALE OF THE MOUNT DIABLO AREA, MIDDLE CALIFORNIA

by

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and

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Deposits composed very largely of radiolarians to which the name radiolarites may be applied, and which are comparable to the radiolarian oozes as found in different oceans are not common, being found only in a few scattered areas throughout the world. They range in age mostly from the Mesozoic to late Cenozoic. One of the best known series of such deposits is found on Barbados Island, making up the Oceanic formation. At the present time these are considered of Eocene and possibly in part lower Oligocene age. Senn(1940, p. 586), one of the latest to discuss these deposits, came to the conclusion that they were formed in deep water comparable to that in which the recent radiolarian oozes are found. Most of the deposits of this type have been considered to have been formed under deep water conditions.

The writers have had occasion to study radiolarian deposits at a number of localities in California which appear to be comparable in lithology and faunal assemblages to the Oceanic formation of Barbados. As the result of this work several papers have already been published. Here we will confine our discussions principally to two shales found in the upper portion of the Eocene series, north and northeast of Mount Diablo (Coast Ranges of middle California). These are the Kellogg and Sidney shales which are described in considerable detail in one of our papers, Clark and Campbell (1942, pp. 5-10). The lower of these two, the Kellogg shale member, has a thickness of about 130 feet; the upper, the Sidney shale, is between 700 and 800 feet thick. Of the two shales the Kellogg is the more homogeneous.

The writers, in discussing the probable conditions of deposition of these two shales, did not come to any definite conclusion regarding the probable depth of water in which they were formed, though it was their opinion that they were probably laid down in fairly deep water. After reviewing the data we are now of the opinion that these beds may have been laid down in comparatively shallow water. The present paper reviews the evidence. As is pointed out later, one of the difficulties in the way of accepting the shallow-water hypothesis is that no similar deposits have been recorded or described which are found in comparatively shallow water or even in moderately deep waters. All of the records that we have been

able to find of radiolarian oozes place them in abyssal depths, below that in which Foraminifera are deposited. Thus it would seem that if we accept the shallow-water hypothesis we will have to postulate conditions of deposition very different from any that are known at the present day.

The following description of the Kellogg shale is taken from the paper by Clark and Campbell (1942, pp. 5-9).

> "The Kellogg shale is very uniform. Some of the layers are thin bedded paper shales. Others seem more massive, breaking out along bedding planes in pieces one-half to one inch thick. Closer examination, however, shows that these thicker beds are actually thinly laminated.
>
> "Most of the shale weathers almost pure white; the unweathered is buff to light chocolate. A notable character is the very small amount of detrital content after washing though a 200-mesh screen, and this consists of Radiolaria, a few Foraminifera, and diatoms. Albert L. Repecka, in reporting on this shale, makes the following observations:
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> "'The Kellogg shale is too fine to make a diagnostic mechanical analysis. It consists mainly of microscopic organic remains mixed in a very fine clay material, the composition of which is indeterminate. There are occasional flakes of quartz, feldspar and mica; and one preparation was observed in which there were abundant angular and isotropic grains seemingly of rhyoltic volcanic glass. All other slides showed only an occasional flake that appeared to be glass. The material is too fine for a positive determination. Some samples contain abundant quartz, feldspar and occasionally a small mica flake; others consist almost entirely of clay and organic material. Flocculation must have been the active process in the deposition of this fine sediment.'
>
> .....
>
> "The principal evidence that may indicate deep-water conditions of deposition is the absence of fossil representatives of other invertebrate groups which are adapted to a bottom habitat and are scarce or entirely lacking in deep water. No remains of corals, brachiopods, bryozoans, echinoderms, or gastropods occur. However, several specimens of a lamellibranch determined as Donax latus Gabb were found; its habitat might very well have been deep water. A few small, imperfect specimens of a species of Nautilus were found; the small size and thinness of the shell suggest that they were young pelagic specimens. A layer of shale, less than one-fourth inch thick, was made up entirely of the translucent carapaces of a shrimplike crustacean.
>
> "From this general lack of bottom forms in the Kellogg shales it would seem likely that if the deposits were laid down in shallow

water some special condition must have been generally unfavorable to bottom life. The general absence of bottom forms and the great abundance of pelagic Foraminifera fit in very well with the hypothesis of deep-water origin."

In reviewing the data we are now of the opinion that this shale was deposited in comparatively shallow water. The most important evidence for which may be summarized as follows: 1) the typical radiolarite grades abruptly downward into fairly coarse sandstones which contain an abundance of shallow-water marine mollusks. 2) Traced for a comparatively short distance to the northwest, it apparently changes to a clay shale. It should be pointed out in this connection, however, that although the clay shales to the northwest are in the same stratigraphic position as the radiolarites to the southeast, the outcrops between the good exposures of these two types of shale are not continuous. 3) The typical radiolarian shale contains a considerable amount of carbonaceous material. Impressions of rushes are fairly abundant and also a few leaf impressions were found. 4) The one pelecypod species found in these beds, Donax latus Gabb, providing the determination is correct (no hinge plate has been exposed), belongs to a genus the species of which are confined to shallow water. 5) The thin-bedded character of the shale points to rhythmic changes which one would not expect to find in deep water. 6) Well defined worm tracks are rather common. 7) A foot-bone of a wading bird was found along with the worm tracks. 8) Some Foraminifera of the bottom-dwelling type are found in the shale, including such genera as Nodosaria, Planularia, and Uvigerina.

The Sidney shale member, which is stratigraphically about 3000 feet above the Kellogg shale, is composed of a much less homogeneous series of beds. It consists of a series of clay shales alternated with beds identical in character to the Kellogg shale. These later beds, sometimes a foot or more in thickness, are made up very largely of Radiolaria together with some Diatoms but with very few Foraminifera. They are identical in lithology to the Kellogg shale. The clay shales with which they alternate contain Foraminifera in considerable abundance, a large proportion of which are bottom forms, and certainly would not be found in depths comparable to that in which the present day radiolarian oozes are found. In the type section of the Sidney shale, as in the Kellogg shales, there is a dearth of larger invertebrate fossils. The general absence of these forms might be cited in support of the deep-water hypothesis.

The evidence that favors the shallow-water hypothesis may be summarized as follows: 1) The alternating character of the typical radiolarites with clay shale which contains well preserved benthonic Foraminifera. 2) The basal portion of the Sidney shales begin with a carbonaceous clay shale, which grades downward into coarse arkosic sandstones. 3) In tracing the Sidney shales to the northwest of the type locality the radiolarites disappear within less than two miles and give way to clay shales, in which casts of pelecypods are fairly abundant. Still farther to the northwest, about one mile, these shales wedge out into the typical coarse arkosic Markley sandstones. In this case the outcrops between the section

containing the radiolarites and that in which they are lacking are continuous.

If we accept the shallow-water hypothesis for the Kellogg and Sidney shale members we encounter a number of difficulties, the most important of which is that no comparable Recent deposits, as far as we have been able to find, have been described from either shallow or even moderately deep water. The second difficulty is the general lack of other bottom types of invertebrates which normally would be expected to be found in shallow or even in moderately deep waters. There is no evidence, however, of stagnant water conditions such as found in the Black Sea. There is no pyrite or sulphur, and the general lithological characters of the deposits are very different from those that are generally thought to have been formed under stagnant water conditions.

Samples of radiolarian earth examined by us from Barbados are similar to these deposits in general lithology and in approximate percentage of wash retained upon a screen. Senn believes these are of deep-water origin (Senn, 1940).

The paleography of the Eocene in the area to the north and east of Mount Diablo is important in connection with the problem of deposition of the two shale members under consideration. These deposits were laid down in an inland sea which came from the northwest, bounded on the east by the Sierra Nevada block, and on the west by a land mass which included the present site of Mount Diablo, and which during Eocene time was part of a large peninsula separating the waters to the north and east from an embayment to the west and southwest. This embayment, locally known as the San Ramon embayment, was only a few miles wide and joined the main inland sea to the northwest. The western portion of the Berkeley Hills and the San Francisco Bay area to the west of the San Ramon embayment formed part of a large land mass separating the embayment from the Pacific Ocean. Beds equivalent in time to the Kellogg and the Sidney shale are not represented in the San Ramon embayment. Apparently the upper Eocene waters in which these shales were laid down never got into the western area. With this in mind one is forced to the conclusion that the western shorelines of the main inland sea during the time of the deposition of the two shales members could not have been very far distant and if these shales were laid down in deep waters then there must have been a deep structural trough or graben fairly close to the shoreline. This would require down folding or faulting of great magnitude. The fairly abrupt transition from shallow water to deep water deposits would require a tectonic depression followed by an equivalent uplift after the deposition of these shales, of which it is hard to conceive, and is very improbable. If the radiolarites should be considered to have been formed at abyssal depths there is required a vertical movement which would be most improbable. Thus it would seem that paleographic and stratigraphic evidence favors the shallow hypothesis.

If the Kellogg and the Sidney shales were deposited in shallow waters it is rather obvious that there could have been no large streams dumping their loads in the near vicinity and that the adjacent land must have been

low. Only such conditions can account for the very small amount of detrital material in the sediments. Judging from the fact that coarse sandstones immediately above and below these shales and into which they apparently grade are arkosic, it seems very doubtful that the climate in that area was humid. In this connection it should be pointed out that the molluscan faunas in the upper Eocene of this region point to a tropical or subtropical temperature. The radiolarian assemblages in these shales as well as the Foraminifera point to oceanic conditions and indicate that there was a direct connection with the Pacific Ocean and this inland sea.

If the radiolarites of the Mount Diablo Area were formed in shallow waters what were the conditions under which the radiolarians were produced in such great quantities? As already pointed out no deposits containing such a great abundance of radiolarians have been noted or described from the present oceans. Their great abundance and excellent preservation in the Eocene deposits of the Mount Diablo Area would seem to show that they lived and multiplied in that area. In fact there must have been an unusual amount of silica in the waters at that time. Like the diatoms in the diatomites their great abundance might indicate that there was an "epidemic" of radiolarians due in part to an excess amount of silica in the water. However, living radiolarians occur in the Pacific mostly in alkaline waters. It is possible that the great amount of silica was the result of volcanism. Small glass shards are fairly common in the shale and it is possible that much of the fine clay was derived from volcanic ash as the result of bentonitization.

One of the questions that is raised is, why the dearth of other invertebrates which normally live on the bottom? The answer would seem to be that the floor was too soft. Most of the clay was probably in a collodial condition, and much of this material was probably held in partial suspension as a gelatinous mass on the sea floor which would smother most of the bottom invertebrates, except a few such as those worms and Foraminifera which may not require abundant oxygen. The presence of many worm tracks indicates that the bottom environment was not lethal. The thin-bedded shale shows that the waters must have been very quiet. The floor was deep enough so that wave action did not disturb the sediments. It would appear that the possibility of a submarine canyon is ruled out by the presence of worm tracks and the lack of coarser beds and cross-bedding in the type-sections.

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PALEOECOLOGY OF SOME OYSTERS

by

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The family Ostreidae is obviously a successful group for it has produced many species and some of the species are very abundant. Around 1000 fossil and Recent species have been described to date, and new species are constantly being added to the list. Some of the species, particularly those adapted to life in shallow and brackish waters, are so numerous that they make up extensive banks of considerable thickness.

Along the coast of Texas old oyster banks are being dredged and the shells used for lime and cement or other industrial uses. In California fossil oysters are being quarried and ground for fertilizer. Needless to say, such industrial uses consume huge quantities of shells and attest to the prolific life of the species that built the banks.

Perhaps no other mollusk was so widespread and obvious during Mesozoic and Cenozoic time as was the oyster. The paleontologist working on the rocks of these eras is well aware of the importance of the oysters. Were one to know more about the life habits of the fossil oysters one might have the key to many ecologic, stratigraphic, and geographic questions.

There is a great deal published on the biology of living oysters, and much information useful to the paleontologist can be culled from the biological literature. A concerted effort should be made to extract those parts of the biological literature that have a bearing on paleontologic research and may lead to a better understanding of fossil oysters. In the following paragraphs some limited use of biological literature is made.

Salinity tolerance of living oysters

Generally oysters are regarded as brackish water animals and very little thought is given to possible differences of salinity tolerance in the various species or genera of the family. Actually the range of salinity tolerance and optimum in which the oysters thrive are different for the various living species.

Observations concerning salinity tolerance can be made along coasts where two or more species of oyster are abundant. For instance, in England there are two abundant species, the native Ostrea edulis Linnaeus and the imported Ostrea (Crassostrea) angulata Lamarck. The former thrives closer to the sea than the latter, and the observations seem to indicate that O. edulis prefers a higher salinity than does O. angulata.

To anyone familiar with oyster "reefs" and their location it is at once obvious that an exact and direct measure of the salinity tolerance of the oysters is impossible to obtain in nature, because the salinity of the water in which a given oyster lives changes continuously. The salinity changes with the tides and currents in the bays; rainfall and fluctuating discharges of the rivers emptying into the bays also produce changes. Therefore, if salinity tolerance is to be measured, experimental laboratory evidence must be used. Amemiya[3] has done that by studying the early developmental stages of oyster species in different salinities. According to this author the salinity tolerances of the early stages are as follows:

	Ostrea (*Ostrea*) *edulis* Linnaeus European oyster	O. (*Crassostrea*) *angulata* Lamarck Portugese oyster	O. (*Crassostrea*) *virginica* Gmelin American east coast oyster
		Salinity percent	
Lowest limit	24	21	15
too low	25-26	22-24	17-21
favorable	27-30	25-27	22-24
optimum	31-35	28-35	25-29
favorable	36-40	36-38	30-33
too high	41-43	39-42	34-38
highest limit	45	43	39

These data apply only to the larval stages before attachment and therefore are not necessarily indicative of adult preferences. However, toward the end of the larval stages the distance a larva may travel is greatly reduced. Therefore, the preferences of the larva are indicative of those of the adult.

Although there is considerable overlap in the salinity tolerance of the three species, there is also considerable diversity. The two species belonging to the subgenus *Crassostrea* have greater tolerance for low salinity than the species of the subgenus *Ostrea*. This difference is in keeping with certain anatomical differences of the soft parts in the two subgenera and with observations on their distribution.

Besides the common shallow-water oysters there are living today oysters which are restricted to deeper waters of normal salinity. McLean[4] described

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[3] Amemiya, I., Notes on experiments on the early developmental stages of the Portuguese, American and English native oysters with special references to the effect of varying salinity: Jour. Marine Biol. Assoc., n.s., vol. 14, pp. 161-175, 1926.

[4] McLean, R. A., The oysters of the western Atlantic: Acad. Nat. Sci. Philadelphia, Notulae Naturae, no. 67, p. 7, 1941.

recently a new species that was dredged from 300 feet depth off Palm Beach, Florida. Only one specimen of this species is known; it was attached to coral.

In the Mediterranean sea there is a well-known deep water oyster, generally known under the name Pycnodonte cochlear (poli). This species is said to be abundant in normal marine waters at a depth of 120 to 200 meters.5/

The Florida species is probably also a member of the genus Pycnodonte or at least closely related to it. It seems that the genus Pycnodonte and its allies live today in deeper and fully marine waters.

This discussion should amply illustrate the fact that the members of the family Ostreidae are greatly diversified as to habitat. There are purely marine, deeper-water species or genera in addition to the brackish water forms. Hence, it is not admissible to assume that fossil oyster banks flourished in brackish water only and it is necessary to investigate each species or group of species separately and to weigh the evidence in each case separately.

Paleoecology of the oysters of the subgenus Cubitostrea from the middle Eocene of the Gulf Coastal Plain

The middle Eocene of the Gulf Coastal Plain contains the following species of Ostrea (Cubitostrea):6/

O. sellaeformis Conrad	Cook Mountain formation
O. divaricata Lea	Cook Mountain formation
O. smithvillensis Harris	Weches formation (upper)
O. lisbonensis Harris	Weches formation (lower)
O. perplicata Dall	Tallahatta formation

5/Pycnodonte Fischer, G. [de Waldheim], Lettre a M. le Baron Ferussac sur quelques genres de coquilles.....: Bull. Soc. Imp. des Naturalistes de Moscou, vol. 8, pp. 117-119, 1835. Genotype species by original designation (p. 119): P. radiata Fischer de Waldheim, n. sp., op. cit., which is probably cospecific with P. vesicularis(Lamarck), Upper Cretaceous. Although Cenozoic Pycnodonts are definitely known to the writer, it has not been possible to study specimens of Pycnodonte cochlear (Poli) so that its generic assignment remains unchecked. L. W. Stephenson seriously doubts the correctness of the reference of P. cochlear to that genus.

6/Cubitostrea Sacco, Federico, I molluschi dei terreni terziarii de Piemonte e della Liguria, vol. 23, p. 12, 1897. Genotype species by original designation: Ostrea cubitus Deshayes, G. P., Description des coquilles fossiles des environs de Paris, vol. 1, pp. 365-366, pl. 47, figs. 12-15, 1824 [1832], from the Auversian of the Paris basin, France.
Cubitostrea has a much longer range in Europe than in North America. Oligocene species are known from England and Germany.

In addition to these 5 species of Cubitostrea there are other species present but these do not belong to the same subgenus and are generally rare. In other words the 5 species are the dominant oysters of the middle Eocene of this region.

Four of these five species form an evolutionary series as follows: Ostrea perplicata Dall ⟶ lisbonensis Harris ⟶ smithvillensis Harris ⟶ sellaeformis Conrad. The fifth species, O. divaricata Lea, is related but does not fit directly in this line of descent. Only recently has it become possible to trace this sequence, because the stratigraphy of the beds and localities involved had been obscure. (Figure 1). It is true that W. H. Dall in 1898[7] and G. D. Harris in 1919[8] had noticed the affinities of some of the species concerned; but having only scanty stratigraphic data available these two authors were unable to realize the chronological sequence of the species and to recognize the stratigraphic independence of the "varieties" they described.

This branch of the family Ostreidae culminates in Ostrea sellaeformis Conrad. This species is a well-known, showy, and abundant oyster useful as a marker of the Cook Mountain formation and equivalent beds. It is most comman in the eastern Gulf states of Alabama and Mississippi, where it occurs abundantly in the upper Lisbon and Wautubbee formations respectively. Westward old and adult specimens with sellate shape fully developed become increasingly rare. The last, that is, westernmost, fully developed specimens of O. sellaeformis are found at Stone City on Brazos River, Burleson County, Texas. There they are restricted for reasons of facies to one layer, the basal bed of the Cook Mountain formation. However, small, immature, and therefore not yet sellate, shells of this species are widely distributed throughout the Cook Mountain formation of Texas. It seems that through most of Cook Mountain time conditions for growth of oysters in Texas were less favorable than in Alabama and Mississippi. Hence the Texas oysters did not reach maturity and did not develop the mature sellate form, except in the interval during which the basal bed of the Cook Mountain was laid down at Stone City on Brazos River.

The Ostrea sellaeformis Conrad has in its mature or senile state a ponderous and peculiarly twisted shell. Its shape suggests a saddle, hence the name sellaeformis. The long axis of the left valuve, anatomically the anterdorsal-posteroventral axis of the animal, is strongly arched. Transverse to the long axis the mature left valve is concavely arched. There are two auricular flaps, one on each side of the umbo, the posterior one the larger; both are arched in a two-fold manner like the main body of the valve. This manifold arching of the various portions of the mature shell produces a rather high and sharp fold in the sinus located between the posterior auricle

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7/Dall, W. H., Contributions to the Tertiary fauna of Florida, etc.: Wagner Free Inst. Trans., vol. 3, pt. 4, pp. 677-678, 1898.

8/Harris, G. D., Pelecypods of the St. Maurice and Claiborne stages: Bull. Amer. Pal., vol. 6, no. 31, pp. 10-14, text fig. 1, 1919.

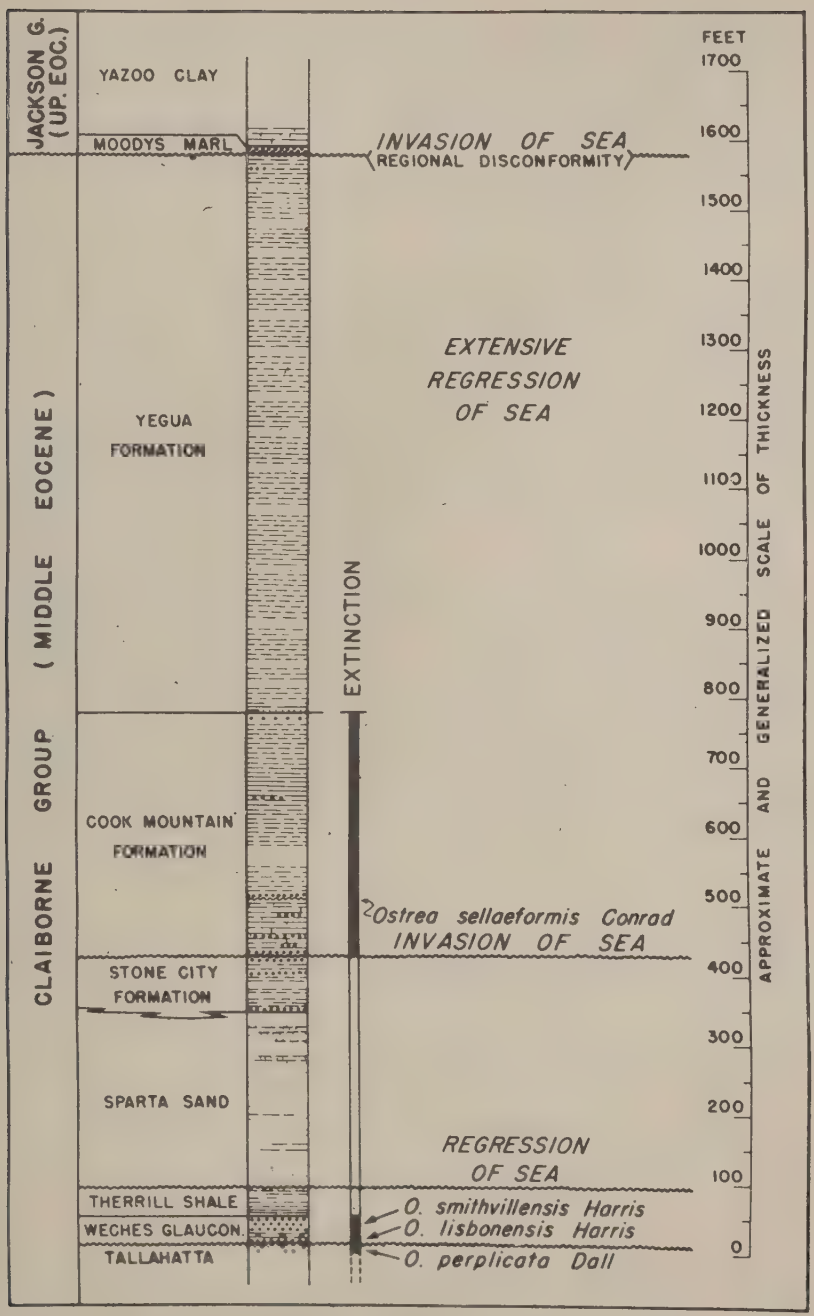

Fig. 1. Stratigraphic distribution of the oysters of the subgenus Cubitostrea in the Gulf Coastal Plain.

and the main shell body, and a much lesser fold in the corresponding sinus between the anterior auricle and the main shell body. The right valve, that is, the unattached valve, conforms to the shape of the left for complete closure of the shell margins, but is so thick and heavy that it too is convex along the long axis, though not as much as the left valve. Surface sculpture consists mainly of crude, projecting, concentric growth lamellae; ribbing is absent over most of the mature surface and very shallow and faint where present.

In contrast to the mature and senile shell is the immature portion preserved near the umbos. This stage is also known from numerous immature fossil shells, which died before reaching maturity. Such shells are thin and not peculiarly twisted and lack the extensive auricles of the adult. Their shell is elongate in outline but curved in a slight crescent. The left, that is, the attached, valve is convex, capacious, and strongly and fairly regularly radially ribbed; the ribs are dichotomous or intercalating and about 1 mm. wide. The right valve is flat to faintly convex and devoid of ribs; regular, concentric, and appressed growth lamellae are the only sculpture present.

The immature shells are an indication of the true affinities of Ostrea sellaeformis Conrad. They are very similar to the immature shells of oysters of the subgenus Cubitostrea.6/ If immature specimens of O. sellaeformis are compared with those of O. cubitus Deshayes and O. plicata (Solander)9/ the great similarity in shape and sculpture is at once. The similarity in youth is so obvious that one can but conclude that O. sellaeformis is a near relative of the two other species or, to put this conclusion into systematic terminology, O. sellaeformis is also a Cubitostrea. This conclusion is merely an example of the procedure W. Garstang10/ had in mind when he discussed critically the Biogenetic Law.

9/Ostrea plicata (Solander) is described as Chama plicata D. C. Solander, n. sp. in Brander, Gustav, Fossilia Hantoniensia collecta et in Musaeo Britannico deposita, pl. 8, figs. 84-85, 1766.

See also Cossmann, M., Catalogue illstre des coquilles fossiles de l'Eocene des environs de Paris, etc., fas. 2: Soc. Royal Malac. Belgique Ann., vol. 22, p. 199, 1887.

Cossmann, M., and Pissarro, G., Iconographie complete des coquilles fossiles de l' Eocene des environs de Paris, vol. 1, pl. 44, figs. 135-36, 1906.

10/Garstang, Walter, The theory of recapitulation: a critical restatement of the Biogenetic Law: Linnean Soc. Jour., vol. 35, no. 232, pp. 81-101, 1922.

The lineage culminating in O. sellaeformis appears first in the middle Eocene as O. perplicata Dall[11] from the Tallahatta formation of Alabama. This species has a strongly ribbed left valve and smooth right valve; it lacks the auricles entirely and for that reason its umbonal region is more pointed than in other species of this stock. In youth its outline is oval to crescentric, but on maturing it expands along the anterior margin so that the shell assumes gradually a curved-triangular outline with one part of the margin nearly straight. The ribbing of the left valve is weak in youth, but becomes stronger with maturity, and at that stage the ribs are wider than their interspaces. The valves are thick as in O. lisbonensis Harris. The species possesses several primitive characters. One is the lack of auricles, which appear for the first time in O. lisbonensis Harris and develop to such an excess in O. sellaeformis Conrad. Another is the peculiar triangular shell outline. This character of O. perplicata Dall is found to be subdued and rare in O. lisbonensis Harris. The indications are that O. perplicata Dall, if not exactly ancestral to the later species, is nonetheless very near to the hypothetical ancestor. At any rate it must be adjudged a primitive form of the stock.

The next species is Ostrea lisbonensis Harris from the Weches formation and its equivalents. (Figure 2). This species is widespread in Alabama, Mississippi, Louisiana, and Texas. It is very similar to O. perplicata. The shell is thick. The umbonal region is wider, because auricles are present. The valve outline is crescentric to oval with an occasional trace of the triangular extension of the shell margin as in O. perplicata Dall. Some specimens have very prominent auricles while others have small ones, but very rarely are traces of this feature entirely absent. The ribbing of the left valve is very similar to O. perplicata Dall, but the interspaces are as wide or wider than the ribs.

The typical, thick-shelled form of O. lisbonensis Harris extends westward to about the center of Leon County in east Texas. To the west of this point there is a gradual transition into local race or ecologic form. The latter form is thinner shelled and more irregular in growth; the ribs are narrower than their interspaces and finer and higher.

Ostrea smithvillensis Harris is also found in the Weches formation, but it is restricted to Texas and occurs always in a higher level than O. lisbonensis Harris. It differs from O. lisbonensis in several respects of which the most diagnostic is the presence of a few low ribs radiating from the beak of the right valve. This species as it grows large assumes an oval outline and its ribs become wider and lower; the auricles are large but in many cases poorly set off from the main body of the valve. The gradual loss of the crescentric shell outline and the change into an oval one, as the shell grows, is an advanced character as is the gradual widening

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[11] Dall, W. H., Contributions to the Tertiary fauna of Florida, etc.: Wagner Free Inst. Trans., vol. 3, pt. 4, pp. 677-678, 1898.

Harris, G. D., Pelecypoda of the St. Maurice and Claiborne stages: Bull. Amer. Pal., vol. 6, no. 31, pp. 10-14, text fig. 1, 1919.

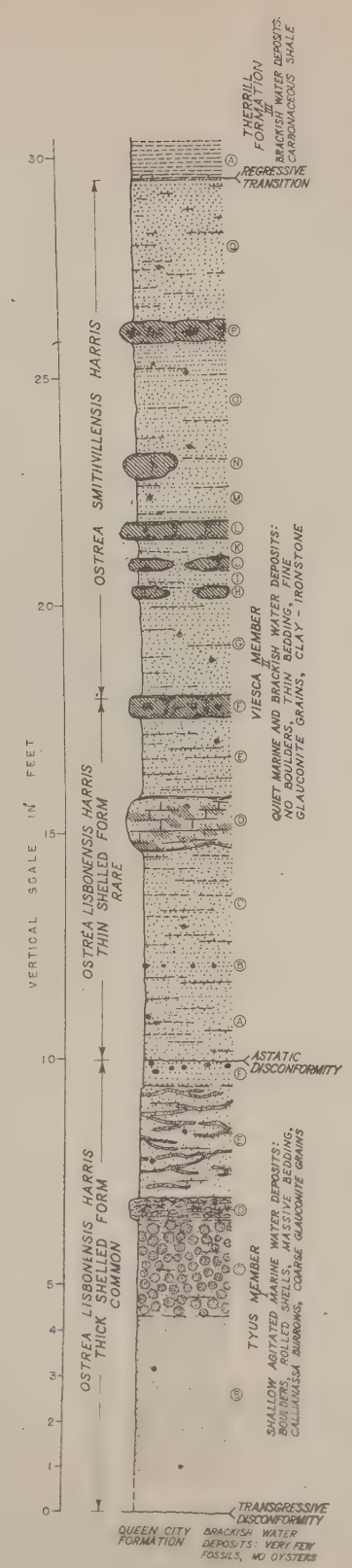

Fig 2 Vertical distribution of the oysters in the Weches formation exposure at Hurricane Shoals, western Houston County, Texas

and weakening of the radial ribs on the left valve. A newly acquired character is the faint radial ribbing of the right valve.

Ostrea sellaeformis Conrad from the Cook Mountain formation and its equivalents is still larger than O. smithvillensis Harris and has in addition acquired a ponderous habit and a twisted shell with large auricular flaps. Due to the twist of the shell the flaps are rather well set off from the main shell body. As the shell grows the ribs of the left valve become more and more obscure. All in all its features are accentuations or exaggerations of the character found already in O. smithvillensis Harris.

This species and the stock it represents disappeared from the Gulf Coast Tertiary with the close of Cook Mountain time. The end of Cook Mountain deposition in the Gulf Coast was marked by a regional and extensive withdrawal of the sea, and the formation succeeding the Cook Mountain is a nonmarine, largely lignitic series of beds known as the Yegua formation.[12] The withdrawal of the sea during Yegua time was certainly of long duration for the formation is a thick one and contains ancient soils with tree roots in situ. The sea withdrew a long way, for the formation can be traced a good distance down dip toward the Gulf before its facies changes to nearshore marine. These extensive shifts in the location of the ancient middle Eocene Gulf shores wiped out the Ostrea sellaeformis stock. When finally the sea readvanced in late Yegua and early Jackson time it returned without a descendant of this ostreid stock.[13] In distinction to the Claiborne group, the Jackson group deposits do not have species of Ostrea (Cubitostrea) as the leading oysters but instead a large species of Gigantostrea, another form whose subgeneric affinities are questionable.

Kellum[14] and Harbison[15] have described Ostrea sellaeformis Conrad from the Castle Hayne marl of North Carolina and the Santee limestone of South Carolina, both Jackson group formations. Kellum did not figure the forms

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[12] Compare Stenzel, H. B., The Yegua problem: Univ. Texas Pub. 3945, pp. 847-910, 1939 [1940].

[13] Ostrea falciformis Conrad, so long regarded as a fossil of the Jackson group, is really a lower Claiborne fossil. It is the same as O. lisbonensis Harris.

[14] Kellum, L. B., Paleontology and stratigraphy of the Castle Hayne and Trent marls in North Carolina: U. S. Geol. Survey Prof. Paper 143, pp. 17-18, 1926

[15] Harbison, Anne, Mollusks from the Eocene Santee limestone, South Carolina: Acad. Nat. Sci. Philadelphia, Notulae Naturae, no. 143, p. 4, pl. 3, fig. 6, 1944.

identified by him as O. sellaeformis and it is not possible to check his identification. Harbison figured a fragmentary specimen, which appears to be O. sellaeformis. It is possible, however, that this fragmentary specimen was reworked from Claiborne beds during the Santee time. According to F. S. MacNeil[16] the separation of the Claiborne from the Jackson group is very difficult in eastern Georgia and other parts of the southern Atlantic Coastal Plain as both groups are smooth limestone. It is conceivable, therefore, that the beds from which Harbison obtained her specimen were misidentified. At any rate neither MacNeil nor the writer has yet found any Ostrea sellaeformis indigenous in deposits of the Jackson group.

Giganostrea trigonalis (Conrad)[17] is one of the abundant oysters throughout the Jackson group deposits from the Moodys marl up into the Danville Landing beds. This is a striking feature of the Jackson group, because Gigantostrea was a very inconspicuous faunal element in the Tertiary before the invasion of the Jackson sea. The other large and abundant oyster of the Jackson group in Ostrea (Subgenus?) gigantissima Finch,[18] which is common in Georgia and southern Texas. The Gigantostrea trigonalis (Conrad) and the Ostrea gigantissima Finch seem to be mutually exclusive; where one is common the other seems absent.

In all cases where data are available to the writer the fossil oysters of the subgenus Cubitostrea are associated with fossils which were most probably truly marine. Among these associates are compound and single corals, such as Amphihelia, Balanophyllia, Endopachys, Flabellum, Madracis, Turbinolia, etc., and echinoids such as the sand dollar Proscutella mississippiensis (Twitchell). Possibly some of the corals could endure brackish water temporarily, but it seems improbable that they thrived in a brackish water environment. These associates indicate that the environment was either truly marine or only slightly brackish or only temporarily brackish. Locally one or another of the associates is quite abundant in the oyster bearing beds. They are not everywhere abundant but at least a few specimens always can be found in the same bed in which the oysters are common. Another characteristic of these beds is that they are not true oyster beds, that is, beds composed overwhelmingly of one oyster species with hardly any admixtures of other fossils. On the contrary, in nearly all instances the oyster beds are multispecific, that is, they contain a rich and varied faunule in which many different biologic groups are represented. It is almost axiomatic that brackish water oyster beds are paucispecific, that is, composed of a very few species some of which may be represented by

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16/Letter dated April 4, 1945.

17/Gigantostrea trigonalis (Conrad) described as Ostrea Conrad, T. A., Observations on the Eocene deposit of Jackson, Miss., with descriptions of thirty-four new species of shells and corals: Acad. Nat. Sci. Philadelphia, Proc., vol. 7, for 1855, p. 259, 1855

18/Compare Howe, H. V., Large oysters from the Gulf Coast Tertiary: Jour. Pal., vol. 11, no. 4, pp. 355-366, 1937.

great hordes of individuals. Brackish water environment is a highly specialized environment into which only a few hardy species can penetrate. These few species are comparatively free of competition and enemies and they can multiply enormously. Paucispecific oyster beds are, of course, known from the Tertiary of the Gulf Coastal Plain, but none of the beds under discussion are of this type.

The distribution of Ostrea lisbonensis Harris is particularly interesting. This species ranges from the typical, heavy-shelled form to a thin-shelled, more irregular form. The forms grade into each other laterally in the strata, but never occur side by side in the same bed. Each is geographically restricted. The heavy-shelled form occurs in the lower Weches formation from central Leon County in east Texas eastward; the thin-shelled form occurs in the same beds westward from central Leon County. Also, as one ascends the stratigraphic column of the lower Weches formation the heavy-shelled form grades upward into the thin-shelled form, but again the two do not occur together in the same bed. The heavy-shelled form occurs only in the lower part of the Weches formation, the strata of which are transgressive over the Queen City formation and rest on that formation with a widespread disconformity.

The typical, heavy-shelled form of Ostrea lisbonensis Harris occurs in the basal, transgressive strata of the Weches formation that show obvious traces of ancient wave action. There are well-rounded boulders of limestone up to 7 inches in diameter with molluscan bore holes, layers of rolled and worn fossil shells, and coarse glauconite grains. The strata tend to be massive, showing few traces of bedding. This seems to indicate that the sediments were repeatedly disturbed, being reworked by waves and by burrowing benthonic shore animals.

The robust build, the thickness of the valves, the simplicity of rib patter, the absence of fine, thin squamate imbrications on the shell of the typical, heavy-shelled form of this oyster are apparently adaptations to life in the zone of wave action and shifting sediments. In this connection it should be noted that the attachment scar of the left valve of this oyster is small or missing. Evidently many individuals were not attached to anything but were lying free on or partly in the bottom sediment. The specimens with small attachment scars were fixed to objects in their youth, but in later life these object were not sufficiently large and heavy to anchor the shells firmly and the animals assumed a virtually free position of repose. Similar conditions are found today among some living oysters.

Wherever the lower Weches strata merge upward into sediments which lack obvious signs of wave action the heavy-shelled form of Ostrea lisbonensis Harris is replaced by the thin-shelled form. The beds which enclose this form are usually shaly and thinly bedded; the glauconite grains are fine. The thin-shelled form is usually associated with other delicate species, such as thin-shelled pectens and fragile bryozoans. Its surface ornamentation consists of fine, thin, squamate imbrications that would not have been preserved had the shell been exposed to wave action.

Among its associates are corals, echinoids, and crabs, but these are usually represented only by a few specimens.

By comparison with the typical, heavy-shelled form of Ostrea lisbonensis Harris, the thin-shelled form looks immature. The former is usually larger and in a given stratum and locality the proportion of large adults to small juveniles is much greater for the heavy-shelled than for the thin-shelled form. A striking feature of the populations of the thin-shelled form in any one exposure is the great number of very young and juvnile shells. These individuals either were buried by sediment before reaching their full size and maturity or died from other natural causes without being incorporated into the sediment immediately. The latter seems more probable because there are no signs of excessively rapid sedimentation in these beds and because in case of quick burial old and fully grown shells should be fairly abundant too. The scarcity of old and fully grown shells of this thin-shelled form is a most striking feature. It seems that the thin-shelled form lived on the fringes of the geographic range of the species where conditions were so unfavorable that only a few individuals reached adult size.

The chief ecologic distribution of this oyster species must have been in the zone of prevalent wave action and in normal marine waters. However, the thin-shelled ecologic form of this species must have lived in quiet waters which may have been slightly less saline than normal marine waters. At no place did even the thin-shelled form enter brackish water lagoons extensively and build large flourishing oyster beds.

PALEOECOLOGICAL CONDITIONS IN THE OZARK REGION IN LOWER ORDOVICIAN (CANADIAN) TIME

by

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The lower Ordovician series of the Ozark region was long regarded as unfossiliferous. In the past thirty-five years, papers by Ulrich (1911), Lee (1913), Weller and St. Clair (1928), Bridge (1930), Ulrich and Cooper (1938), Ulrich, Foerste, Miller et all (1942) 1943) (1944), and Cullison (1944) have gradually increased knowledge of the faunas of this 2200 foot section of dominantly calcareous rocks. The part of the Ozark dome where beds of lower Ordovician age outcrop includes the central and eastern part of the south half of Missouri and extends into the northern tier of counties in Arkansas. It is the largest exposure of lower Ordovician formations in the central interior of North America and is one of the largest on the continent. Except in strictly paleontological papers the above mentioned authors have all been consistent in pointing out that the faunas are found in zones, dominantly as silicified molds in chert, and that appreciable thicknesses of unfossiliferous dolomite are present between the zones. These apparently unfossiliferous beds constitute at least 75 percent of the 2200 feet of section. The paleoecology of the black shale facies of the lower Ordovician has been discussed by Ruedemann (1934) but very little has been written concerning that of the calcareous facies. Because of this lack, a number of hypotheses must be considered in attempting to explain the nonfossiliferous nature of the major part of the section. The more probable are as follows: 1) the unfossiliferous beds may not have been examined sufficiently; 2) dolomitization may have destroyed the included fossils; 3) the fossils which are known are predominantly molds in chert: similar types of fossils may be present in beds which are not chertified; 4) the unfossiliferous beds represent deposition in seas which were inhospitable to life and the faunal zones represent short periods of time during which animals and plants migrated into the area only to be forced out again by the return of the earlier environment.

Workers who have studied the section have a reputation for thoroughness in field work and this would seem to eliminate the first of the hypotheses mentioned above. A survey of the faunas, floras, types of sedimentary structures and fossil occurrences in the lower Ordovician formations may provide sufficient information to decide which one or which combination of the remaining hypotheses approaches the correct explanation.

The lower Ordovician of the Ozark region in Missouri and Arkansas consists of the following formations.

Black Rock formation
Smithville formation

Powell dolomite
Cotter dolomite
Theodosia formation
Rich Fountain formation
Roubidoux formation
Gasconade dolomite (restricted)
Van Buren formation

The above 2200 foot section consists of dolomite, dolomitic limestone, chert, sandstone and shale, arranged in the order of importance.

Bridge (1930) in his chapter on "Geologic History" in the report on the Eminence and Cardareva quadrangles gives the best available information on the ecological conditions of the Van Buren and Gasconade seas. The advancing sea entered a region of considerable relief and the initial deposits were sandstone and conglomerate. This sea was shallow and the later sediments varied from sandstone to sediments which are now medium to coarse-grained dolomites. These deposits represent the Gunter member of the Van Buren formation. They were succeeded by fine-grained argillaceous dolomite, indicating a sedimentary environment in which much clay, silt, and argillaceous material were accumulating. These beds were succeeded by coarse-grained dolomite which represents a return to purer calcareous sedimentation. The fauna of the Gunter member is very poorly preserved, but its existence is known from silicified fragmental remains. No fauna has been found in the fine-grained argillaceous dolomites which overlie it. Overlying these fine-grained beds is a 12 to 18 inch bed of coarse-grained dolomite. This bed is commonly cherty and drusy after weathering and the next few feet of beds above contain the dominant fauna of the Van Buren. Above this to the top of the formation few if any fossils have been found in finer grained beds. Bridge (1930) has suggested that this sea ranged in depth from zero to 100 fathoms. In the part of his report devoted to structure he showed that the initial dips of the Ozark region compare favorably with those now prevailing on the Great Bahama bank. It should be pointed out that the deposits on the Great Bahama bank at the present time contain few marine shells. In this respect the sediments which formed the fine grained Van Buren dolomites appear to have been similar to the Drewite of the Bahama bank because neither is known to carry fossils. The fauna of the Van Buren is dominated by small, straight or slightly curved cephalapods of the genera Burenoceras and Dakeoceras, the low spired gastropod genera Sinuopea and Ophileta, and the slightly higher spired genus Schizopea. The algal growths called Cryptozoa are common throughout the formation. The absence of sand indicates that land masses were low and small or else remote -- hence the development of a bank of calcareous mud rather than normal littoral deposits.

The Gasconade dolomite is in many respects similar to the Van Buren. Much of the dolomite, especially in the lower portion, is fine grained and nonfossiliferous. Bridge (1930) points out the occurrence of the Euomphalopsis zone about 50 feet above the base, the Ozarkina zone just below an algal biostrome, and the upper very fossiliferous zone in the top of the formation. He further states that the beds between the two lower

zones are only sparingly fossiliferous. Algal growths are common in these beds, but it is believed that the great algal biostrome located 40 to 70 feet below the top of the formation represents the beginning of a shallower sea condition which prevailed in the Ozark region with but slight interruptions until the end of the lower Ordovician. In the cherts derived from the weathering of the coarse-grained dolomites above this biostrome, fossils are most abundant. The size of the cephalapods has increased even though the forms are still straight or slightly curved. The gastropod genus Ophileta appears in its maximum size and is represented by a number of species. Schizopea and Sinuopea known from the Van Buren are again present. A new high spired genus is Gasconadia, and a new low spired one is Helicotoma. The cap-shaped gastropods are present. Numerous species of the trilobite genus Hystricurus appear and brachiopods are represented by Finkelnburgia and Syntrophina. The fauna of this upper zone represents the first well balanced shore fauna in the lower Ordovician, and it was deposited in a shallow sea which was spread widely over the Ozark region. Bridge (1930) suggests a shallowing of the seas toward the end of Gasconade time. If this is true, the adjacent land areas were contributing little silt to the area. This is suggested by the general absence of argillaceous materials which resulted in a more favorable environment for organisms.

During Roubidoux time the sea became even shallower than during the deposition of the earlier formations. This fact is attested by the abundance of sand, ripple marks and sun cracks. These are present in all of the four sandstone members which are separated by three dolomite members. Mud cracks and ripple marks are found sparingly in the latter -- a further indication of shallow water conditions. The fauna is known from two zones. The lower, just above the basal sandstone member contains the brachiopod Syntrophina campbelli and the large low spired gastropod Roubidouxia umbilicata. The upper, as known to date, consists entirely of species of the gastropod genus Lecanospira which is present in the dolomitic fifth member. This zone is known throughout the area and is widely known in North America east of the 110° meridian. The fact that these two zones are in coarsely crystalline dolomite suggests that the seas were slightly deeper and the source areas of the sediments were lower at these times than during the deposition of the sandstone and argillaceous dolomite members in which the suncracks and ripple marks are found.

The major part of the Rich Fountain formation consists of fine-grained, light grey, buff-weathering dolomite, locally called "Cotton Rock ", with irregular sandstone lenses scattered through it. The lower part of the formation is dominated by coarser-grained crystalline grey siliceous dolomite, the most massive unit of which is called the School Mine ledge. Below this ledge and above the top of the Roubidoux the transition zone consists of siliceous oolite, cotton rock and chert. No complete analyses of the cotton rock are available but insoluble residues disclose residual clay and much silt. Samples of a typical cotton rock collected from a quarry in the upper Rich Fountain north of Rolla, Missouri have yielded an average of 18 percent clay and silt by weight. The silt and clay, because of their flocculent nature, probably had a greater influence on the living conditions on the sea bottom during deposition than the percentage would indicate. Siliceous

oolites are common throughout this formation and thin irregular ripple-marked, cross-bedded, and suncracked sandstones are numerous as discontinuous lenticular bodies. External molds of salt crystals were noted by Muilenburg and Alger in the cotton rock near DeSoto, Missouri during the summer of 1936. (Personal communication April 1944 by G. A. Muilenburg). The top of the massive coarse-grained dolomite is about 25 feet above the base of the Rich Fountain. In the top of this, the School Mine ledge, the sponges Archaeoscyphia annulata and Ozarkocoelia irregularis are commonly present, but at some localities they dominate the fauna to the exclusion of all other forms. The trilobite genus Jeffersonia characterizes the zone from the top of the School Mine lege upward for 30 feet. Caphalapods, both the nautiloid and straight type as well as small low spired gastropods are almost always present in varying abundance. A few brachiopods have been collected from this zone. This fauna has been traced throughout the Ozark region. The cotton rock which composes the upper part of the formation carries no known fauna except for a few linguloid brachiopods.

The Theodosia formation resembles the Rich Fountain formation lithologically. Near the middle it contains two sandstones and a siliceous oolite bed which are remarkably persistent. About 30 feet above the base there is a coarse-grained dolomite which on the outcrop is very similar to the School Mine ledge. In the top of this massive member and for the next 20 feet upward the formation is fossiliferous and contains a great abundance of both low and high spired gastropods chiefly of the genera Hormotoma and Orospira as well as a few representatives of the small nautaloid cephalapod genus, Shumardoceras. The Hormatoma and Shumardoceras are commonly present in a dark grey chert bed about 2 to 4 inches thick which is a coquina-like bed of shells and shell fragments. This thin bed has been traced widely through the southern part of Missouri. The middle of the formation, above the oolite, includes the two sandstone members and dolomite beds. The dolomites immediately below, between, and above these sandstones are usually granular and contain numerous layers which are exceedingly fossiliferous. Above this faunal zone to the top of the formation the rock is typical barren cotton rock.

The Cotter dolomite contains three faunal zones. The lower zone about 50 feet above the base is in a coarse-grained dolomite that carries a typical Cotter fauna composed of gastropods, trilobites and cephalapods. Below this, the dolomites are fined-grained and argillaceous and have yielded no fossils. About the middle of the formation, above a heavy sandstone lens in the type section, a gastropod zone, only sparsely fossiliferous, is known. About 50 feet below the top of the formation in porous chert, formed by the weathering of a granular dolomite, is found the upper Ceratopea and gastropod zone. Between these faunal zones, and upward to the top of the formation, the beds are cotton rock.

The Powell dolomite contains more shale beds than all of the preceding formations. These olive green shales near the base of the formations are barren of fossils. McKnight (1935) noted the presence of salt hoppers, external moulds of halite crystals, in one of the shale beds near Yellville, Arkansas. Sun cracks and ripple marks are common in the dolomite -

which is fine-grained and argillaceous except for the "Black Ledge". This ledge, a massive coarse-grained dolomite, occurs about 40 feet above the base and contains all of the known Powell fauna. Nautaloid cephalapods, trilobites, brachiopods, and both low and high spired gastropods are present. Above this rock is an argillaceous dolomitic limestone in which no fossils have been found.

The Smithville and Black Rock formations insofar as they are known are argillaceous fine-grained dolomitic limestone. Two faunal zones are known from the Smithville. One carries an abundant graptolite fauna and has been collected from the dump at a mine shaft north of Smithville, Arkansas, but has not been found on the surface. The rock is fine-grained light grey argillaceous dolomite. The other fauna is very abundant and is found as silicified internal and external molds in the residuum around the old zinc diggings on the Imboden road north of Smithville. Ceratopea, numerous other genera of gastropods, cephalapods, brachiopods, and ostracodes are all abundant in this particular zone. The beds from which they weather appear to contain less silt and mud than the nonfossiliferous beds with which they are associated.

One faunal zone is known from the Black Rock formation. It is present in the quarry south of Black Rock, Arkansas, where the new highway bridge abutment is built over the old road. Sponges, trilobites, and gastropods have been collected from a crystalline dolomitic limestone bed at this locality. The beds both above and below are finer grained and much more argillaceous.

Summary: All of the beds in the above formations have been subjected more or less equally to conditions which caused dolomitization. The differences which may be noted in the present lithology are in part due to the differences in the character of the original sediments. The same inference can be made in regard to silicification except that it must be modified to suit present surface weathering conditions. Internal and external molds of fossils in crystalline dolomite have been collected from the Cotter. This suggests that silicification is not a necessary requisite for preservation but serves to make the fossils more conspicuous. Bridge (1930) pointed this out in his discussion of the algal biostrome in the Gasconade. The algal remains are present in the dolomites even in vertical cliffs but are apparent only where they have been silicified, usually on the less steep slopes. Practically all of the silicification which preserves the fossils is related to surface weathering and this is greatly influenced by topography and by forest cover. No fossils except a few linguloid brachiopods have been obtained from the cotton rock. This rock dominates the entire section and inasmuch as it contains a high percentage of mud and silt, a muddy bottom condition must have prevailed during much of lower Ordovician time. The presence of oolites, thin sandstone lenses, sun cracks, and ripple marks all indicate that the water was shallow. The presence of salt hoppers in the Rich Fountain cotton rock and Powell shale beds indicates hypersaline conditions. These beds are not fossiliferous. It is probable that the shallow sea which covered this area during lower Ordovician time generally had a higher than average salinity because of evaporation and poor

circulation. Occasionally, due perhaps to eustatic changes, better marine circulation was achieved throughout the region and at the same time the inflow of fine detrital material diminshed. This allowed purer calcareous deposits to accumulate and the fauna of the time to invade the area temporarily and be included in these and a few of the overlying beds, only to be forced out again on the return of inhospitable conditions. The general absence of graptolites, the dominant planktonic form of the epoch, suggests that the factor which eliminated them from this area was salinity rather than bottom conditions. Nicol (1944), in his analysis of the Schizodus faunule of the Kaibab formation near Flagstaff, Arizona, points out the fact that bottom conditions and hypersalinity restrict the representation in that faunule to gastropods, pelecypods and cephalapods. Due to the absence of pelecypods in lower Ordovician time we find that a number of the faunules are represented by cephalapods and gastropods only. Where brachiopods are found there is usually a greater abundance of all forms, including trilobites and occasionally sponges.

Conclusion: It is believed that the lower Ordovician sediments were deposited in seas which were commonly muddy, shallow and hypersaline. Such conditions make the sea inhospitable to benthonic and planktonic organisms. The faunas which are present represent short periods of time when the above conditions did not prevail to such an extent as totally to exclude the marine animals of the period. The various faunules reflect variations in the degree to which these habitable seas were hospitable during these parts of the Ordovician period.

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SHALLOW WATER FISH FAUNAS FROM THE MIOCENE OF CALIFORNIA

by

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Fossil shallow water fish faunas have rarely been found in California's deposits because, apparently, fish remains are seldom preserved in sandstones and conglomerates and are not usually well preserved in massive sandy silts. The shallow water faunas found near the northeastern border of the middle Miocene Los Angeles Basin are therefore of interest. These are found in siltstones, probably of lower Luisian or upper Relizian age of foraminiferal evolution. The siltstones are underlain by extensive volcanics and volcanics may also occur between the siltstone units. Some fish remains found in these deposits are: (1) Numerous scales of large porgyfish related to the pinfish "Lagodon"; (2) Silverside scales from the subfamily atherininae are very abundant in places; this subfamily includes the tropical forms of the living American silverside, whereas the silversides of the upper Miocene belong to the subfamily Atherinopsinae including the jacksmelts, grunions and others; the Atherinopsinae existed all through the Miocene. (3) Several herrings, the most abundant being the roundherring related to "Etrumeus". (4) Scales of the family Gerridae, the mojarras; these are rare. (5) Heterosomata, flatfishes, and Sciaenidae, croakers. All the above forms are characteristically shorefishes, that may have lived along sandy beaches.

Another characteristic shallow water fish fauna occurs in the lower Miocene Saucesian of Foraminiferal evolution of the Santa Barbara, San Marcus and Eastern Santa Maria Basin. It is found in deposits of interchanging sands and siltstones. Shallow water faunas in this area are found only locally while neighboring areas show fish of deeper habitats. The most characteristic fish scales in these strata are large scales of a round herring and numerous scales of porgyfishes. The most abundant porgyfish is represented by a relatively small scale that may be related to Pagella (Calamus), but various others, some of which are of considerable size, are present. A shad related to Ganolytes, but with much more irregular ornamentation is common. Serranidae, groupers, related to Myctoperca and possibly Paralabrax are characteristic. There are a number of Sciaenidae, croakers, which usually indicates nearness of freshwater. The scale of a small smelt of the family Atherinopsinae is characterized by its tubercular ornamentation. Mackerela (Scomber) and jacks (Caranx)? are present. Shallow water habitat is clearly indicated by the abundant porgies and roundherrings and substantiated by the presence of croakers, groupers, flatfishes, smelts, jacks and mackerels.

SUMMARY OF ECOLOGICAL STUDIES ON INVERTEBRATES OF THE TEXAS COAST

by

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1. Data on invertebrates was collected from March, 1941 to November, 1942 in Copano Bay, Aransas Bay and the adjacent parts of the Gulf of Mexico during a study devoted chiefly to fishes. The most intensive work was carried on from June, 1941 to August, 1942, inclusive. The area studied extended from the headwaters of Copano Bay to 5 miles offshore in the Gulf of Mexico with a salinity gradient from almost fresh water to pure sea water in a running distance of 40 nautical miles. Minnow seines, trammel nets, beach seines and shrimp trawls were used in collecting. Descriptions of the area, stations, methods of collecting, data on fishes, and summary of the temperature and salinity data are published elsewhere (Gunter, Pub. of Institute of Marine Science, Univ. of Texas, vol. 1, no. 1, 1945).

2. Approximately 72,000 specimens of invertebrates, chiefly crustacea, were caught. The peneid shrimp Penaeus setiferus and P. aztecus (mixed with P. duoarum) the grass shrimp, Palaemonetes, the blue crab, Callinectes sapidus, and the sea pansy, Renilla mulleri were the most common species. Renilla mulleri, a creeping coelenterate, was found only in the Gulf, while the greatest numbers of the other species were caught in the bays. Shrimp of the family Penaeidae are the predominant invertebrates of Texas coastal waters. Penaeus setiferus and P. aztecus (with P. duoarum) together made up approximately 82 per cent of the numbers of invertebrates. Two other peneids Xiphopeneus kroyeri and Trachypeneus constrictus were caught in some numbers in the Gulf. The crustacean species were probably taken in numbers more or less proportional to their abundance, but certain others, such as starfish and sand dollars were probably present in much greater numbers than the catches show. The oyster Ostrea virginica, is an abundant invertebrate growing in large "reefs" in the bays. It is not ordinarily caught by the collecting gear used in this study and there is no basis for comparison of its abundance with the more numerous invertebrates (crustaceans) taken in the course of this work.

3. The invertebrate population of the bays is made up chiefly of the peneid shrimp, Penaeus setiferus and P. aztecus, the blue crab, Callinectes sapidus, and the grass shrimp, chiefly Palaemonetes vulgaris. Grass shrimp are restricted to the flats and shallows of the bay shores, while the other species are found all over the bays. The average size of shrimp and crabs from shallow waters was smaller than examples of the same species from deeper waters, but neither small nor large individuals were restricted to either place.

4. Most species can withstand high salinities, but many can not withstand low salinities and therefore the number of species caught in the Gulf

was much greater than the number in the bays. Eight species were caught in Copano Bay, 24 in Aransas Bay and 42 in the Gulf.

5. The fauna of brackish waters is marine and is not derived from fresh water. As the waters become fresher along the salinity gradient, certain invertebrates that can not tolerate lowered salinities drop out of the picture, but others persist. There is no compensating increase in the number of species by invasion of species from fresh water and therefore number of species in waters of low salinity is low, but those present are marine.

6. Many species grow up in the bays during the warmer months. Certain Gulf species invade the bays in the spring and summer. When the temperatures drop in the fall a great part of the population begins to move to or towards the Gulf. Many species leave the bays entirely in winter and, therefore, the number of species in the bay declines. Similarly certain Gulf species move out to deeper water and disappear. There is also a movement of crustacea away from the shallows near shore in the fall and early winter. A similar migration was found among the fishes and more noticeable in Aransas Bay and the Gulf than in Copano Bay. The most striking seaward movement is that of the common commercial shrimp. When the temperatures rise in the spring-most species spawn and the young start growing up in the bays again. Seasonal variations in abundance of the invertebrates as a whole in the bays are dominated by changes in the population of the 4 species present in greatest numbers, namely Penaeus setiferus, P. aztecus, Callinectes sapidus and the grass shrimp, Palaemonetes. Variations in numbers in the Gulf largely involved population changes of the coelenterate, Renilla mulleri and the crustaceans, Penaeus setiferus, Xiphopeneus kroyeri and Callinectes danae. In general the summer and fall were the seasons of greatest catches in the trammel nets, beach nets and minnow seines, or in other words in shallow waters. The average catch showed a sharp decline in winter, except in minnow seine hauls in Copano Bay. In trawls the greatest average catch in the Gulf was in the spring and the lowest was in winter. In both bays the fall was the season of greatest average catch in trawls. In Copano Bay the smallest catches were in winter, but in Aransas Bay it fell in summer. In general, trawl catches were least in summer and greatest in the fall.

7. Invertebrates in less salty water usually average smaller than those of the same species in higher salinities. In general there is a direct correlation between size and salinity.

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